# MONTHLY NOTICES

OF THE

# ROYAL ASTRONOMICAL SOCIETY

CONTAINING

PAPERS, ABSTRACTS OF PAPERS, AND REPORTS
OF THE PROCEEDINGS OF THE SOCIETY
1946

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Vol. 106 No. 1

## ADDITIONAL MEETING OF 1946 JANUARY 14

Sir Harold Spencer Jones, Vice-President, in the Chair

The Chairman expressed the regret of the President for being prevented by indisposition from attending the meeting and welcomed the French astronomers in whose honour the meeting had been arranged. He referred to the recent death of Professor Charles Fabry, an Associate of the Society, and paid a short tribute to him (the Fellows standing).

Forty-six presents were announced as having been received since the last meeting, including:—

*Mathematical Reviews*, Volumes I–V (presented by Professor L. M. Milne-Thomson); *Communications des Laboratoires de l'Institut d'Optique*, I–VII (presented by l'Institut d'Optique).

The Chairman announced that the Council had awarded the Gold Medal of the Society to Professor Jan Hendrik Oort, of the University of Leiden, for his investigations on the dynamics and rotation of the galactic system. He announced also that Professor Oort had been invited to give the George Darwin Lecture for 1946.

The Chairman announced that the Council had awarded a Jackson-Gwilt Medal and Gift to Mr. Harold William Newton, of the Royal Observatory, Greenwich, for his work on the Sun, notably on the relation between solar flares and magnetic storms.

Dr. Bernard Lyot signed the Admission Book as an Associate.

The Chairman called upon Professor A. Danjon, Dr. D. Chalonge, Dr. A. Couder, Monsieur C. Fehrenbach and Dr. B. Lyot in turn to give an account of the work on which they had been engaged during the war; Dr. D. Chalonge also gave an account of the work done by Professor J. Dufay, who had been prevented by indisposition from accompanying his colleagues. Dr. Lyot also showed a series of very fine cinematograph films of solar phenomena which he had taken at the Pic du Midi Observatory. These included shots of the chromosphere in the light of $H\alpha$ seen both in elevation at the Sun's limb and projected on the disk surrounding an active spot-group. Another film, taken by integrated light under exceptionally fine conditions, illustrated the short life-time of the solar granulations. The most impressive film was, however, of the corona showing coronal details taken simultaneously with the monochromator in the light of three different wave-lengths—the coronal green line, the coronal red line and $H\alpha$.

## ANNIVERSARY MEETING OF 1946 FEBRUARY 8

Professor H. H. Plaskett, President, in the Chair

The election by the Council of the following Fellows was duly confirmed:—

Kenneth Douglas Adams, c/o National Broadcasting Service, Invercargill-Dacre R.D., Southland, New Zealand;

Gerard P. Kuiper, Yerkes Observatory, Williams Bay, Wis., U.S.A.;

Bert Walter McMullen, 3 Fiveways, Ickenham Road, Ruislip, Middlesex;

Limmye Vernon Robinson, Department of Mathematics, Emory University, Georgia, U.S.A.;

George Philip Sidney Streatfeild, B.A., 1 Alverton Place, Penzance, Cornwall.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Norman Wilson Allison, B.Sc., 439 Leasons Road, Moreton, Wirral, Cheshire (proposed by J. Proudman);

Mahmoud Khairy Mohamed Aly, Solar Physics Observatory, Cambridge (proposed by F. J. M. Stratton);

Noel Atherton, 5 Kipling Avenue, Bath, Somerset (proposed by D. H. Sadler);

Gerald M. Clemence, U.S. Naval Observatory, Washington 25, D.C., U.S.A. (proposed by L. J. Comrie);

George Henry Corbett, 34 Butleigh Avenue, Victoria Park, Cardiff, Glamorganshire (proposed by C. Evans);

John Logan Lewis, B.A., The College, Eastbourne, Sussex (proposed by H. A. Brück);

Edward Thomas Pierce, Solar Physics Observatory, Cambridge (proposed by F. J. M. Stratton);

John Robert Pikett, 93 Whitmore Road, Harrow, Middlesex (proposed by D. Brunt);

William Hugh Cowie Romanis, M.A., M.Ch., F.R.C.S., 149 Harley Street, London, W. 1 (proposed by E. W. Barnes);

John M. C. Scott, M.A., 37 Church Street, Malvern, Worcestershire (proposed by H. R. Hulme);

James Willoughby Somers, B.Sc., 37 Couston Street, Dunfermline, Fife (proposed by E. M. Lindsay);

Harry Verdon Stopes-Roe, Norbury Park, Dorking, Surrey (proposed by H. Dingle);

Frank Tyler, B.Sc., Ph.D., 47 Colenso Road, Blackburn, Lancashire (proposed by B. M. Holden);

Thomas James Willmore, M.Sc., Ph.D., Research and Development Establishment, Cardington, Bedford (proposed by G. Temple).

Fifty-seven presents were announced as having been received since the last meeting.

The President announced that Professor J. H. Oort, Gold Medallist for 1946, would deliver the George Darwin Lecture at the Ordinary Meeting on 1946 May 10 on "Some Problems Concerning Interstellar Matter".

The President in presenting the Jackson-Gwilt Medal and Gift to Mr. Harold William Newton, of the Royal Observatory, Greenwich, to whom it had been awarded for his work on the Sun, notably on the relation between solar flares and magnetic storms, spoke as follows:—

The Jackson-Gwilt Medal and Gift are awarded at intervals of not less than three

years, as a rule to gifted amateur astronomers, and we recall with pleasure the awards in recent years to Dr. Waterfield, to Mr. Hargreaves and to Mr. Ryves. This year Council has reverted to the practice which led to the award of the Medal to Mr. Melotte in 1909, and has chosen for this honour another professional astronomer, also of the Royal Observatory, Mr. Harold William Newton. The award is a recognition of his brilliant work with the spectrohelioscope.

The spectrohelioscope in a form satisfactory for instantaneous, monochromatic observation of a large portion of the solar disk was first brought into use by Hale in 1924. By 1928 the original instrument had been considerably improved, and by 1931 no less than 25 of these inexpensive instruments were in use at various observatories, including in particular one at the Royal Observatory, Greenwich. At this time it seemed probable that the spectrohelioscope could only be used for detecting disturbed regions on the solar disk, that is acting as a "finder" for the more elaborate spectrographs and spectroheliographs, and even in the hands of Hale himself little more than this was achieved. It is to our medallist that astronomers primarily owe the realization that the spectrohelioscope is one of the fundamental tools in astrophysical and geophysical research.

Even in his earliest use of the instrument (*M.N.*, **90**, 820, 1930) Mr. Newton recognized the two characteristic solar phenomena of very bright, short-lived *Hα*-flocculi with little or no radial motion, and associated with them dark flocculi characterized by large radial motions. In subsequent papers, sometimes alone and sometimes in collaboration, he developed several satisfactory methods and ultimately a very simple one for the measurement of the ratio of surface brightness in the bright *Hα*-flocculus to that in the adjacent continuous spectrum (*M.N.*, **99**, 463, 1939); as a result of these photometric studies he was able to distinguish the rather rare occurrence of exceedingly bright flocculi to which he applied the name "solar flares", now generally recognized (*Pub. Ast. Soc. Pac.*, **56**, 156, 1944) as the simplest term descriptive of the observed phenomena. The similarity of these flares observed with the spectrohelioscope in the light of *Hα*, and the bright solar eruption of 1859, observed by Carrington and Hodgson in integrated light, with which a large magnetic storm was associated, led Mr. Newton (*M.N.*, **103**, 244, 1943) firmly to establish a connection between the solar flare and two terrestrial magnetic phenomena—a simultaneously occurring "crotchet" on magnetic traces, and, some twenty-one hours later, a "great" magnetic storm. In 1935 Dr. J. H. Dellinger, of the Bureau of Standards, described a number of sudden fade-outs in the transmission of high frequency wireless waves and suggested that these might be associated with some solar phenomenon. This suggestion was later independently examined by our medallist (*M.N.*, **97**, 594, 1937) and Dr. Dellinger (*Terr. Mag.*, **42**, 49, 1937), and they succeeded in establishing that the fade-out occurred at the same time as a solar flare appeared.

In addition to his work on solar flares proper, Mr. Newton has given attention to the dark marking with large radial motions which are associated with these flares. In two important papers (*M.N.*, **95**, 650, 1935; **102**, 2, 1942) which summarize his skilful observations of the very transient phenomena involved, he has established that with the onset of the flare the dark marking shows an outward motion with a velocity probably as high as 100 km. per sec., this marking steadily loses its outward velocity, at the same time fading in intensity, and reappears as a fading rapidly inward moving object. There can be little doubt, as our medallist has suggested, that these dark markings in motion are prominences seen in projection on the solar disk.

Mr. Newton, in handing you this afternoon this Jackson-Gwilt Medal and Gift, Fellows will wish me to express the very great admiration which we all have for your work and the hope that you long may be able to inspire and direct the work which you have so brilliantly initiated.

The President then delivered his Address on "Astronomical Telescopes" (see p. 80).

## 1946 FEBRUARY 8

## ANNUAL GENERAL MEETING

Professor H. H. Plaskett, President, in the Chair

The Minutes of the preceding Annual General Meeting were read, confirmed and signed.

The Minutes of the Special General Meeting of 1945 October 12 were read, confirmed and signed.

The President having appointed the Scrutineers, the Society proceeded to the ballot for Officers and Council for the ensuing year.

The Secretary read extracts from the Narrative Report of the Council.

The Report of the Honorary Auditors was read (see p. 12).

The Treasurer remarked on a few items in the Accounts relative to the financial state of the Society.

A vote of thanks to the Honorary Auditors of the Treasurer's Accounts for 1945 was proposed and carried unanimously.

It was proposed and carried that the Report of the Council be received and adopted, and that it be printed and circulated in the usual manner, together with the Report of the Honorary Auditors and the President's Addresses.

The Secretaries proposed, on behalf of the Council, the following amended Bye-laws, which were put to the Meeting and adopted unanimously:—

### Section III.—*Of the Election of the Officers and Council*

7. If, in the interval between any two successive Annual General Meetings, the office of President, Vice-President, Treasurer, Secretary, or Member of Council may have become vacant by death, resignation or otherwise, the Council shall have power to fill such office until the next Annual General Meeting.

### Section VII.—*Of the Council*

39. Minutes of the proceedings of the Council shall be taken during their progress by one of the Secretaries, which shall be afterwards fairly entered (as early as convenient) into the Minute-book, and the accuracy of such entry having been confirmed at the next meeting of the Council shall be signed by the President or other Fellow then in the chair.

### Section VIII.—*Of the Ordinary Meetings*

40. The ordinary meetings of the Society shall be held on the second Friday in every month during the Session, from October to May *, both inclusive: and twelve Fellows shall constitute a quorum. But, when the second Friday happens to be *Good Friday*, the meeting shall be held on the *Wednesday* preceding.

* It is at the option of the Council, at their discretion, to insert or omit, year by year, the month of June in the list of ordinary meetings.

41. Business shall commence at half-past four o'clock in the afternoon *precisely*, when the minutes of the preceding meeting shall be read, and the minutes of the Council, laid on the table, for the inspection of the Fellows, if required.

### Section IX.—*Of the Annual General Meeting*

46. A General Meeting of the Society shall be held annually on the second Friday in February, immediately following the ordinary meeting, to receive the Report of the Council on the state of the Society, and to deliberate thereon; to discuss and determine such questions as may be proposed relative to the affairs of the Society; to elect the Officers for the ensuing year; and to enact, alter or repeal Bye-laws, agreeably to the recommendations of the Council, on proper notice given thereto according to the Charter.

48. Notice of business to be brought forward by the Council at the Annual General Meeting shall be posted to every Fellow at least one week before the date of meeting.

49. The President, or other Fellow in the chair, shall appoint two or more scrutineers, from amongst the Fellows present, to superintend the ballot during its progress, and to report the result to the Meeting. The ballot shall commence and close at the pleasure of the Meeting.

### Section XVII.—*Of the Hannah Jackson* (née *Gwilt*) *Medal*

77. The award of the Hannah Jackson (*née* Gwilt) Medal shall be made by the Council at intervals of not less than three nor more than seven years.

78. The award shall consist of a money grant and a Bronze Medal.

The Secretaries proposed, on behalf of the Council, the following motion, which was carried unanimously:—

> THAT certain manuscript meteorological observations made at Cordoba in the years 1813 and 1814 be presented to the Royal Meteorological Society.

The Scrutineers reported to the President the result of the ballot, and the names of the Officers and Council elected for the ensuing year were read to the Meeting. (The list of names is given on p. 95.)

The thanks of the Society were given to the retiring Vice-Presidents (Dr. E. C. Bullard, Sir Harold Spencer Jones, Mr. F. J. Sellers), Treasurer (Mr. J. H. Reynolds), Secretary (Dr. H. R. Hulme) and other retiring Members of the Council.

The thanks of the Meeting were given to the Scrutineers of the ballot.

The Meeting then adjourned.

# REPORT OF THE COUNCIL TO THE HUNDRED AND TWENTY-SIXTH ANNUAL GENERAL MEETING OF THE SOCIETY

1. *General.*—The end of the war in Europe, followed so quickly by that in Asia, marks an epoch which is no less important and significant in the affairs of the Society than in those of the world in general. Its immediate effect on the Society was not large—the ending of black-out regulations, the cessation of fireguard duty in Burlington House are relatively minor matters—but ever since there has been a gradual heightening of interest in astronomy. Firstly, contacts with astronomers of the occupied countries of Europe have shown us that enthusiasm can overcome even the obstacles of occupation by a foreign Power; secondly, astronomers, led appropriately by the President and the Foreign Secretary, are returning from their war-time work to infuse fresh life and ideas into those few who remained; thirdly, there is the promise of an increase in the number of original scientific contributions, upon which both the publications and the meetings of the Society depend; fourthly, there is a greater interest in the general organisation of astronomy and the planning of research, both nationally and internationally. The Society has a considerable part to play in the building-up of British astronomy; it must not only reinstate all its pre-war activities at the earliest possible date, but must also be prepared to support new ideas and to inaugurate new functions. In particular, the war has intensified interest in astronomy—the black-out and navigation in astronomy proper, the atomic bomb in astrophysics and the stellar laboratories. The Society must assume some responsibility for maintaining this interest.

As will be seen from the detailed report that follows, it is far from easy even to return to the adequate exercise of the full pre-war activities. The improvement over the previous year has not been very marked, except in relation to the return to a more normal schedule of meetings. The printing position has been more difficult and, in spite of the advertised facilities, no slides or prints have been available for sale. The return to Burlington House of the Society's valuable books and other property provides the opportunity for expressing here the Society's deep gratitude to the Director of the University Observatory, Oxford, and to the Director of the Solar Physics Observatory, Cambridge, for having provided safe storage space for these irreplaceable documents throughout the war.

During the year the Society was asked by the Scientific Film Association to consider if it could help the Association with its production of astronomical films. A joint Committee meeting was held with the British Astronomical Association, and it was agreed to give all possible help and advice to the Scientific Film Association in their work.

Attention must be called to the revision of the scale of Composition Fees, mentioned in detail in the section on *Finance* below, and to its broad implications. It is clear that the Society's expenditure, largely consisting of the two items of staff and printing, must rise with increasing wages and other costs, while the Society's income, both from investments and from contributions, remains fixed. The increase in Composition Fees must therefore be regarded as anticipating a rise in the annual contribution, though the Council is desirous of delaying such an increase until it becomes essential.

This Report of the Council follows the standardised form. Obituary Notices of deceased Fellows and Associates, Proceedings of Observatories and Notes on the Progress of Astronomy are included in the usual manner.

2. *Bye-laws.*—At a Special General Meeting on October 12 the Society repealed Bye-laws 41A and 87, which had been adopted at the Special General Meeting of 1939 November 10, thus bringing to an end the war-time emergency powers by which the Council could, in effect, set aside the existing Bye-laws. It was not possible to include the repeal of Bye-laws 26A and 26B as, in many cases, the circumstances under which Fellows have suspended their Fellowship still operate and may continue to do so for some time. The change in the wording of Bye-law 26A, adopted in 1944, will enable the Council to act according to prevailing circumstances, particularly as regards the transfer of currency; the Council has no immediate intention of limiting the duration of these Bye-laws for those to whom they continue to apply.

At the same meeting the Fellows approved a revised form of Bye-law 23, which in effect increased the scale of Composition Fees. Later, the Council considered the position concerning Composition Fees for Fellows on the Suspense Account and agreed upon the following interpretation of the revised Bye-law:

"In the case of Fellows who have taken advantage of Bye-laws 26A and 26B to suspend their Fellowship, the Council is agreed that it cannot treat their Fellowship as continuous for the purpose of calculating composition fees according to Bye-law 23. It accordingly rules that in these cases, the composition fee payable at any time shall be that according to Bye-law 23, on the assumption of continuous Fellowship, *increased* by one guinea for each year of non-contributory Fellowship below the age of thirty and by one half-guinea for each such year above the age of thirty."

During the year the Council has given detailed consideration to the relation between current practice and the detailed wording of the Bye-laws. As a result, several alterations to the Bye-laws, mainly of a minor character but including one or two of principle, will be brought forward for the consideration of Fellows at the Annual General Meeting in February 1946.

A new edition of the Bye-laws, incorporating these changes and including dates of adoption and amendment, will then be prepared.

3. *Membership.*—The Council record with regret the death of two Associates (Count F. M. da Costa Lôbo and Marie Paul Auguste Charles Fabry) and of twenty-three Fellows; their deaths occurred in 1945 except where an earlier year is indicated. Obituary Notices are given on pp. 26–43.

*Hugh Lancelot Aldis
Ashton Charles Allen
Robert Ballard
William Ira Brown (1944)
John Edmund Calthrop
*William Ernest Cooper
John Edmund Drower
*Alexander Davidson Fleming
*Walter Frederick Gale
*Arthur Robert Hinks
John Robert Fisher Jeffreys (1944)
Peter Kennedy
Alexei Nikolayevich Kriloff
Edward Ayearst Reeves
*Frank Robbins
*Arthur Laidlaw Selby (1942)
William Napier Shaw
Alan James Skinner
Frederick Slocum
Edward Bruce Herschel Wade
Ernest Wunderlich
James Young
Meade Lafayette Zimmer

*Life Fellow.

A table giving detailed statistics of the membership of the Society on 1946 January 1 is given on p. 13. It is encouraging to note the increased number of elections in 1945, this being the largest for many years.

4. *Finance.*—The Annual Accounts from 1945 January 1 to December 31 have been audited by the professional auditors, Messrs. Sharp, Parsons & Co., and certified correct.

The Cash Account shows a cash balance at the Westminster Bank, Post Office Savings Bank, and in the London Savings Bank on 1945 December 31 of £6315, 10s. 6d., compared with £5451, 4s. 0d. on 1945 January 1.

The Revenue Account shows a net surplus of £71, 10s. 10d. after making the annual reserve of £40 for repairs, £100 for the Staff Pension Fund, and a new reserve of £100 for binding war-time periodicals.

The Suspense Account (unpaid contributions and Admission Fees) at 1945 December 31 amounted to £1038, 9s. 0d. This amount represents the total of the Suspense Account and is not included in the Balance Sheet. It is most probable that only a small proportion of this amount will ever be realised. At the same time, there have been certain payments made during the year on account of contributions owing for years previous to 1945, and such amounts have been included in the Revenue Account for the present year.

The margin of excess of Revenue over Expenditure and Reserves, £71, 10s. 10d., is not large, and an increase in the cost of printing and other expenses, which may be expected in the future, would make it difficult to balance Expenditure and Revenue. It may therefore be necessary to look to some other source for increasing the Revenue of the Society.

It has been apparent for many years that the Composition Fee of 30 guineas for Life Fellowship with a reduction of 1 guinea per year after the first 5 years of Fellowship gave an undue advantage to a newly elected Fellow who compounded at an age under thirty. In view of this anomaly, and also of a possibility that the Annual Contribution may have to be advanced at some future date, it was resolved at a Special General Meeting held on 1945 October 12 that the Composition Fee should be advanced to 45 guineas, with certain modifications depending on age at election and length of Fellowship.

5. *Meetings during 1945.*—The Annual General Meeting was held in April and there were seven Ordinary Meetings, in March, May, June, July, October, November and December. As in previous war-time years, meetings began at $16^h\ 30^m$ and were timed to end at $18^h$, though increasing advantage was taken of the understanding that extension beyond this time was possible. The average attendance of Fellows (as shown by the signatures in the Attendance Book, and excluding visitors) was 56 as compared with 55 in 1944.

The George Darwin Lecture was delivered at the October meeting, and four of the remaining meetings were devoted to the reading of original papers communicated to the Society; owing to the shortage of original papers suitable for presentation, organised discussions were arranged for the meetings in June and July, the first being on the subject of "Extra-Galactic Nebulæ" and the second being devoted to accounts of various new theories of the origin of the solar system. The Council is most grateful to those Fellows who contributed to these successful and enjoyable discussions.

During the war the Society has adhered to a summer session instead of to the winter session as laid down in the Bye-laws. In this year of reversion to the existing Bye-laws there has of necessity been some coalescence between the two, requiring detailed adjustment; this was made at the Special General Meeting on October 12, when it was agreed to hold meetings at the earlier hour of $16^h\ 30^m$ in the months of November, December and February (1946). The Council considered very carefully what arrangements for the dates and times of meetings would be the most generally acceptable to Fellows and decided to obtain guidance by means of a postal ballot. As a result, the Council decided to propose, at the Annual General Meeting in February 1946, alterations to the months in which regular meetings are scheduled to be held and a continuance of a time of meeting of $16^h\ 30^m$ instead of the pre-war $17^h$. For the time being, meetings will continue to be arranged to terminate at some time between $18^h$ and $18^h\ 30^m$, according to circumstances.

6. *Geophysical Discussions.*—A Geophysical Discussion was held in March, the subject being "The Thermal History of the Earth". A more comprehensive programme of meetings is being arranged for 1946.

7. *George Darwin Lecture.*—Professor Bengt Edlén, of Uppsala, Sweden, gave the George Darwin Lecture at the Ordinary Meeting on October 12, taking as his subject "The Origin of the Emission Lines in the Coronal Spectrum". This address is printed in *M.N.*, **105**, 323.

8. *Awards and Elections.*—The Council awarded the Gold Medal of the Society to Professor Bengt Edlén for his identification of the origin of the principal lines in the coronal spectrum. The President's address on the award is printed in *M.N.*, **105**, 138.

Professor William Otto Brunner and Professor Marcel Gilles Jozef Minnaert were elected Associates of the Society.

9. *Publications.*—During 1945 the Society published Vol. **105** of *Monthly Notices*, though owing to difficulties of printing only four numbers of the volume have been actually distributed during the year. One number, Vol. 5, No. 4, of the *Geophysical Supplement* was issued.

As in previous war-time years, the volume of *Monthly Notices* has been restricted to six numbers only, not associated with particular monthly meetings. The total number of pages in Vol. **105** is 394, as compared with 340 in Vol. **104** and the pre-war average of 800; when account is taken of the increased type area and smaller type, it will be seen that the total amount of matter printed is much more than half the average. The Council has decided to continue to restrict *Monthly Notices* to six numbers for at least another year. Apart from the possible shortage of material, which it is hoped will not last much longer, the insuperable difficulty in returning to monthly publication is the uncertainty over the time to be allowed for all stages of the printing. While the present shortage of man-power in the printing industry continues, and especially of compositors experienced in mathematical work, Fellows must accept delay and irregularity of publication.

With the omission of the Ordinary Meeting in January 1946 the Annual Report of the Council will appear in the first number of Vol. **106**.

The publication of the number of *Occasional Notes*, which as announced under this heading last year is to contain a translation of the Preface and Book I of *De Revolutionibus* by Copernicus, has been seriously delayed; it is hoped that it will be issued to Fellows early in 1946. The general revival of *Occasional Notes* is conditional on an informal understanding with the Editors of *The Observatory*, according to which *Occasional Notes* will be published only when it contains material not suitable for inclusion in *The Observatory* (as, for example, the series of translations of early astronomical works) or when there is adequate material for both publications.

10. *Exchange of Publications.*—The Society has again been indebted to the American Committee for the Continued Distribution of Astronomical Literature for copies of publications it would not otherwise have received, for its regular *Bulletins* and for distributing copies of *Monthly Astronomical News Letter*. With the resumption of more normal methods of communication the Committee has now ceased its activity. The Council has expressed the Society's appreciation of and gratitude for the Committee's services to Astronomy to its Chairman, Dr. Bart J. Bok.

The Society is also indebted to private individuals; in particular to Dr. G. P. Kuiper, who took copies of *Monthly Notices* to Europe before postal services were restored, and, even before the end of the European War, brought back astronomical literature from Germany and the occupied countries, and to Dr. Chalonge, who presented microfilms of German publications to the Society.

The distribution of *Monthly Notices* to countries with which normal communication is still impracticable has again been greatly assisted by the Astronomer Royal and by the British Council. The policy in force last year is being continued, but of course on a much larger scale; it is still not practicable to make up war-time gaps for all the Institutions on the exchange list, though this is done as soon as possible for the most active Institutions. The rapid restoration of full postal services is enabling the resumption of the dispatch of current publications. It will take a long time, however, to reach the steady state which is a desirable prelude to the revision of the exchange list, and to effect the complete interchange of missing numbers of observatory and other publications. Many problems also arise in relation to the publications of ex-enemy countries, and it is not yet clear how the Society will be able to complete its sets, especially in cases where the stocks have been dispersed or destroyed.

The list of *Exchanges* has again been omitted from the Report.

11. *The Library.*—The use made of the Library remains about constant and, in 1945, 370 books were borrowed by 96 different borrowers, as compared with the figures of 395 books and 90 different borrowers in the previous year. Many Fellows use the Library for consultation; such visits amount to over 1000 annually.

Three lists of *Additions to the Library* (other than by exchange) were issued during 1945. It is hoped to obtain copies of the few astronomical books published in Germany during the war.

The more rare and valuable books have now been returned to Burlington House from Oxford and Cambridge, although it has not yet been possible to unpack them all. Even so the colourful sight of the Grove-Hills collection in their delightful bindings, back once more in the Grove-Hills Library, must have heartened many Fellows.

During the year the Council reconsidered how best it could distribute the collection of astronomical books and periodicals which it had made for the purpose of restocking destroyed or damaged astronomical libraries. It is satisfied that the organization of the Inter-Allied Book Centre offers the safest medium for ensuring that the books are used to their fullest advantage; it has therefore been decided to hand over the books to the Centre for distribution, having first inserted a suitable book-plate stating the origin and medium of distribution.

The promises of the early resumption of full exchange of periodicals, and the filling of war-time gaps, has intensified the problem of shortage of library space, especially for periodicals. The Council is giving earnest consideration to proposals from the Library Committee for providing more shelf space. It is certain that, without this, the long-awaited and much-needed rearrangement of the Library will not be possible. Although a selection of periodicals has already been made to be offered for incorporation in the central library of the proposed central home for science, it is realized that, in the present circumstances, it may be many years before the project materializes.

For still another year it has not proved possible to undertake any binding.

12. *The Society's Office and Staff.*—For the greater part of the year the Assistant Secertary, Miss E. Wadsworth, was alone with only part-time clerical assistance from Mrs. U. M. Dewey and, for part of the year, from Lady Walton. In October the Society was fortunate in obtaining the permission of the Ministry of Labour and National Service to engage Miss Jean Bower as full-time shorthand typist, and she commenced duty on October 29. Mrs. Dewey will continue to give part-time assistance. The Society owes much to Miss Wadsworth for the way in which she is carrying out the very heavy duties of her post with insufficient assistance. The Council is hoping that it may shortly be possible to provide further staff to help with the war-time arrears of work and the many problems of reconstruction.

In anticipation of this, the Council is considering the use of the Outer Office (at present largely used as a cloak-room) as an office proper.

13. *The Society's Property and Instruments.*—The Society's valuable property, stored throughout the war at the University Observatory, Oxford, has now been returned to Burlington House. Fellows can once again inspect the working of the Harrison clock, kindly set-up by Lieut.-Commander Rupert T. Gould (see the note p. 12). Stocks of publications stored both at Oxford and at the Solar Physics Observatory, Cambridge, have also been returned.

Portraits of the Rev. Lewis Evans and the Rev. William Pearson, presented to the Society during the war years, have been hung.

The following instruments have been presented to the Society:—

$3\frac{1}{2}$-inch Refractor by Cooke with accessories, Spectroscope by Hilger, two Transit Instruments, all belonging to the late A. C. Allen and presented to the Society by his daughter.

German Astronomical Computer, the ARG I, presented by Wing Commander R. S. J. Edwards.

No changes have been made in the disposition of the Society's instruments during the year. The optical parts of the instruments housed at the Headley Observatory have been removed, and are now stored at Burlington House and at the Royal Observatory, Greenwich. The revised list of instruments is still in preparation.

No new slides or celestial photographs have been added to the Society's collection during the year. Further, it has still proved impossible to implement the promise of copies for sale made earlier in the year; every effort is being made to find a suitable firm able and willing to make slides and prints up to the Society's standard, but the demand is large and the facilities available small. The Council is fully alive to the essential nature of this part of the Society's activities, and realizes that not only must it be resumed as soon as possible, but that the gap of six years without additions must be made good.

14. "*The Observatory*".—In accordance with the agreement of 1941, Fellows have received the six 1945 issues of the magazine. The Editors have co-operated with the Council in the insertion of notices and information of particular interest to Fellows. Fellows are reminded that information about the Society's activities (for instance, details of papers available in microfilm form) will often be published solely in the pages of *The Observatory*.

During the year a fresh and somewhat simplified agreement was reached with the Editors, extending the original period indefinitely. Under this agreement the distribution of the magazine will be solely the responsibility of the Society, who will decide whether any particular number is to be sent out separately or held until the next number of *Monthly Notices*.

15. *The British Astronomical Association.*—During 1945 the British Astronomical Association continued to hold both Ordinary and Council meetings on the Society's premises. The Association's Library is open to members from $13^h$ to $16^h$ on Wednesdays.

On 1945 October 13 the Council gave notice to the British Astronomical Association of the Society's desire to terminate the present agreement (which under the terms of the agreement was due for review at the end of the war), but indicated its clear intention of negotiating a new agreement before the expiration of the one year's notice.

16. *The London Mathematical Society.*—Meetings of the London Mathematical Society were held on five occasions in the Society's rooms. The Society has now resumed its normal programme of meetings.

17. *Lectures for the Forces.*—The lectures on astronomy for members of the British and Allied Forces given in the Society's rooms in the winter months of 1944–1945 in collaboration with the British Astronomical Association were most successful and attracted large and enthusiastic audiences. Reports of the lectures will be found in *The Observatory*.

In view of the greatly reduced demand, the series is not, however, being continued.

## NOTE ON THE SOCIETY'S HARRISON CLOCK

The accompanying photographs show the Society's Harrison Clock as again mounted in the Grove-Hills Library. It was originally installed there in 1929 (see *M.N.*, **89**, 398, 1929), but was dismantled shortly before the outbreak of the war in 1939, and has remained in storage until recently.

A shows the complete mounting. The glass top, front and sides of the case, which form a single unit, have been removed temporarily while the photographs were taken. To eliminate vibration as far as possible, the bottom of the case does not rest on the floor, but clears it by about three inches. The overall height from the top of the case to the floor is approximately 7 feet 5 inches.

B gives a close-up view of the movement, the original portion of which terminates at the upper surfaces of the supporting brackets. These were fitted during the overhaul of the clock in 1927–29, as also were the thermometer, the degree-plate, the pendulum and the driving-weight. The last-named (20 lb.) does not drive the clock directly, but merely rewinds, every 30 seconds, a small spiral-spring remontoire which impels the escape-wheel. The pendulum was copied (by the late Mr. J. H. Agar Baugh) from that of a clock by Harrison belonging to the Clockmakers' Company. The degree-plate is graduated to 8° on either side of the dead-point. Normally, the pendulum traverses a total arc of approximately 13°.

C is another close-up which gives some idea of the clock's complexity (it contains, in all, some 540 separate parts). The weight of the clock is chiefly taken upon the two A-brackets, which are bolted to a substantial iron back-plate which, in turn, is bolted directly to the library wall. The wooden back-board of the glass case—which, as the photograph shows, is packed out to a distance of about 2 inches from the wall itself—is perforated to clear the iron back-plate. In this manner the considerable weight of the clock and its show-case is spread over as large an area of the wall as possible, one set of wall-plugs taking that of the clock, and a second, widely separated, set that of the case.

RUPERT T. GOULD.

## REPORT OF THE AUDITORS FOR THE YEAR 1945

The accounts of the Society have been examined and certified correct by the professional accountants, Messrs. Sharp, Parsons & Co. We have checked the official list of Fellows against subscriptions received, a substantial number of which have been forthcoming from Fellows in arrears with payments.

A sharp increase in membership has restored to the Society a nominal strength in excess of that possessed by it in 1938—the year preceding the outbreak of war. This increase is offset at present by the number of non-active Fellows (89), but if this number is deducted from the total, the remainder still exceeds any comparable figure since 1940.

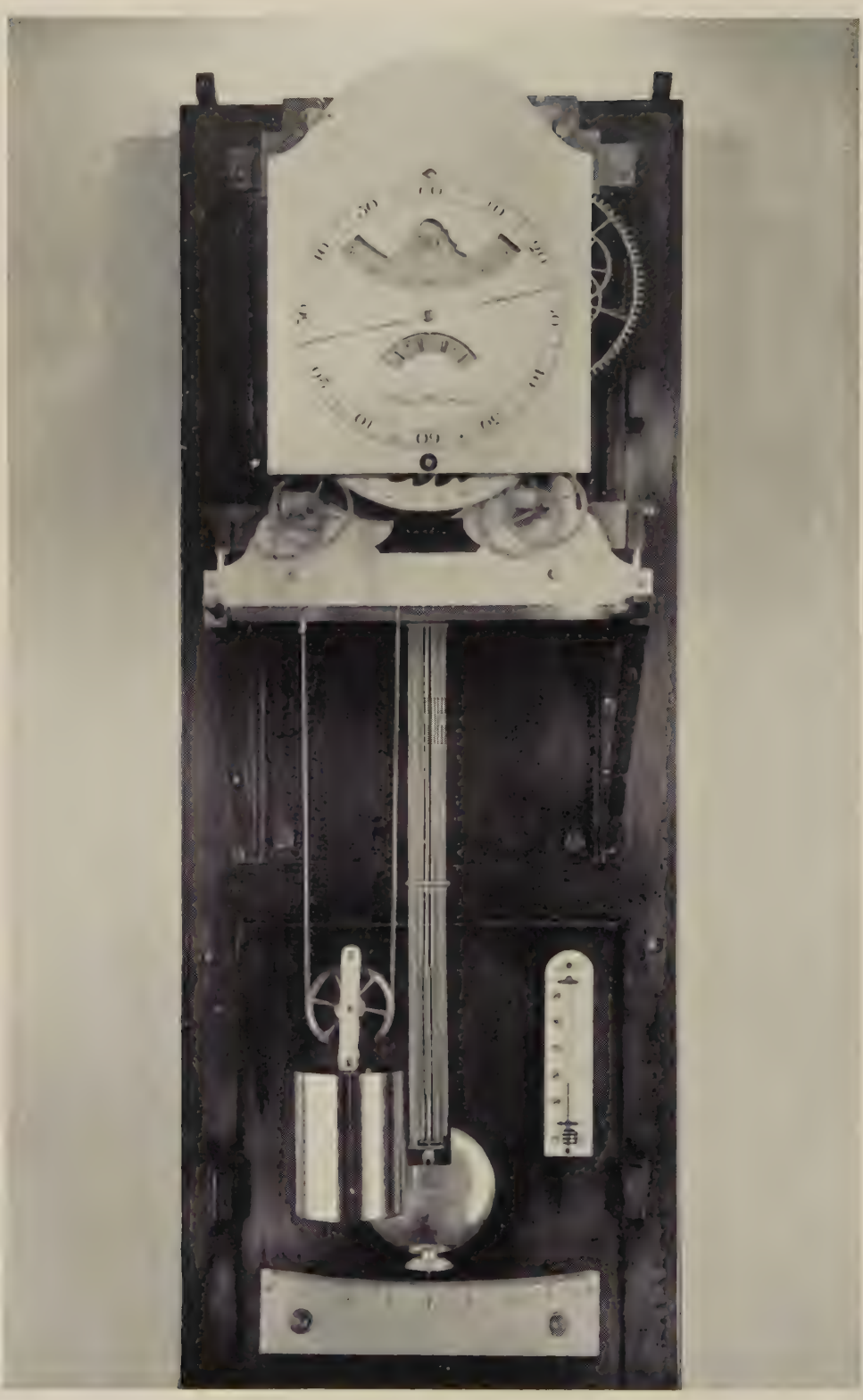
These comparisons with earlier years are in themselves encouraging, but the gradual return of peace-time conditions is making itself evident in other ways in the affairs of the Society, and will inevitably give rise to a number of problems in the near future. Post-war conditions cannot be the same as those existing before the war, and for this reason we view with some concern the meagre balance of revenue over expenditure revealed in the Balance Sheet. This balance of £71, 10*s.* 10*d.* leaves the Society with little margin to further the improvements in hand, and to face further possible expenditure.

We have examined the premises, and note that steps are being taken to meet the ever pressing demand for increased library accommodation.

We wish to acknowledge with gratitude the helpful co-operation of the Assistant Secretary in providing us with all the information and explanations that we required.

J. G. PORTER.
H. F. FINCH.

A. The complete mounting.



B. The movement, front view.

C. The movement, side view.

*R. T. Gould. Note on the Society's Harrison Clock.*

## PROGRESS AND PRESENT STATE OF THE SOCIETY

| | Patron | Institutional Members | Fellows | | | Associates | Total |
|---|---|---|---|---|---|---|---|
| | | | Compounders | Annual Subscribers | Non-active Fellows | | |
| 1945 January 1 ... ... ... ... | 1 | 5 | 179 | 564 | 102 | 47 | 898 |
| Since elected ... ... ... ... ... | ... | ... | + 3 | +46 | ... | +2 | ... |
| Election void † ... ... ... ... | ... | ... | ... | − 1 | ... | ... | ... |
| Resignation cancelled ... ... ... | ... | ... | ... | + 1 | ... | ... | ... |
| Deceased 1945 ... ... ... ... | ... | ... | − 6 | −13 | ... | −2 | ... |
| Deceased prior to 1945, death not notified ... ... ... ... ... | ... | ... | − 1 | − 3 | ... | ... | ... |
| Resigned 1945 ... ... ... ... | ... | ... | ... | − 3 | − 2 | ... | ... |
| Since compounded ... ... ... | ... | ... | +19 | −19 | ... | ... | ... |
| *Suspense Account*— | | | | | | | |
| Added 1945: | | | | | | | |
| (*a*) Contributions unobtainable under War conditions | ... | ... | ... | − 1 | + 1 | ... | ... |
| (*b*) Under Bye-law 26A ... ... | ... | ... | ... | − 2 | + 2 | ... | ... |
| (*c*) Under Bye-law 26B ... ... | ... | ... | ... | ... | + 1 | ... | ... |
| Transferred 1945: | | | | | | | |
| (*a*) From "War conditions" 1944 to Bye-law 26B ... | ... | ... | ... | ... | − 1 | ... | ... |
| (*b*) From Non-active 1944 to Active ... ... ... ... | ... | ... | + 2 | +12 | −14 | ... | ... |
| 1946 January 1 ... ... ... ... | 1 | 5 | 196 | 581 | 89 | 47 | 919 * |

(* As far as can be ascertained under present circumstances.)
(† Rev. Harold William Heaslip, elected 1943 September 10, election unratified.)

(Nine Associates are also Fellows, and are therefore counted twice in the above table.)

*Cash*

RECEIVED

| | £ s. d. | £ s. d. |
|---|---|---|
| **Balances, 1945 January 1:—** | | |
| In hand of Assistant Secretary, on Petty Cash Account | 5 19 4 | |
| At Westminster Bank, on Current Account | 440 3 9 | |
| **At Westminster Bank, on "B" Account:—** | | |
| A. S. Williams Bequest | 52 10 0 | |
| **At Westminster Bank, on "C" Account:—** | | |
| Trust Funds £254 16 6 | | |
| Sales of Duplicate Books Fund 1 3 8 | | |
| | 256 0 2 | |
| **At Post Office Savings Bank:—** | | |
| General Fund £2,140 19 8 | | |
| "C" Account 655 1 2 | | |
| Staff Pension Fund 250 0 0 | | |
| | 3,046 0 10 | |
| **At London Savings Bank:—** | | |
| Ordinary Department (including £250 A. S. Williams Bequest) £1,100 6 6 | | |
| Special Investment Department 556 2 9 | | |
| | 1,656 9 3 | 5,457 3 4 |
| **Dividends on Investments** | 625 0 0 | |
| **Interest on Savings Banks Deposits** | 111 8 5 | |
| **Income Tax refunded:** 1944 April–December £146 5 8 | | |
| 1945 January–April 93 0 0 | | |
| | 239 5 8 | |
| **Sales of Publications:—** | | |
| For 1945 £218 9 1 | | |
| Due in 1942 (including postages) 0 2 6 | | |
| Due in 1943 ( „ „ ) 2 2 0 | | |
| Due in 1944 8 19 11 | | |
| 1946 in advance 24 8 0 | | |
| | 254 1 6 | |
| **Reprints:—** | | |
| For 1945 £5 18 0 | | |
| Due in 1944 1 16 0 | | |
| | 7 14 0 | |
| **Sale of Photographs and Hire of Slides** | 3 17 6 | |
| **Miscellaneous Receipts:—** | | |
| London Mathematical Society £12 0 0 | | |
| Assistant Secretary, Contributions to Pension Scheme, 1944 August–1945 December 24 15 10 | | |
| Hire of Adding Machine 1 1 0 | | |
| Excess on Contributions 1 8 10 | | |
| Postages repaid: 1944 0 16 1 | | |
| 1945 15 9 10 | | |
| Postages 1946, paid in advance 2 12 6 | | |
| British Astronomical Association, 1944 12 10 0 | | |
| British Astronomical Association, 1945 37 10 0 | | |
| British Astronomical Association, Lectures for the Forces, 1944 6 14 10 | | |
| Headley Observatory, Repairs, 1944 1 5 0 | | |
| | 116 3 11 | 1,357 11 0 |
| **Received on Account of Contributions:—** | | |
| 488½ Annual Contributions, 1945, and £1, 2s. to complete Contribution £1,026 19 0 | | |
| 4 Institutional Membership Fees, 1945 8 8 0 | | |
| 26 Annual Contributions, 1946, in advance 54 12 0 | | |
| 2 Contributions, 1947, in advance 4 4 0 | | |
| 1 Annual Contribution, 1948, and Part Contribution, 1949, in advance 3 14 0 | | |
| 42 Admission Fees, 1945 88 4 0 | | |
| 39 First Contributions, 1945 74 11 0 | | |
| | 1,260 12 0 | |
| **Arrears paid off:—** | | |
| 1922–24, written off and now repaid £6 6 0 | | |
| 1940 8 8 0 | | |
| 1941 12 12 0 | | |
| 1942 18 18 0 | | |
| 1943 18 18 0 | | |
| 1944 (including 1 Institutional Membership Fee) 48 6 0 | | |
| Admission Fee, 1940 2 2 0 | | |
| Admission Fees and First Contributions, 1944 8 8 0 | | |
| | 123 18 0 | |
| **Compositions:—** | | |
| 1 Initial (Fellow elected 1941 May) £31 10 0 | | |
| 1 „ (Fellow elected 1944 December) 31 10 0 | | |
| 3 „ (Fellows elected 1945) 94 10 0 | | |
| 19 Reduced 324 9 0 | | |
| | 481 19 0 | 1,866 9 0 |
| **"C" Account:—** | | |
| Dividends on Investments | 169 13 4 | |
| Income Tax refunded: 1944 April–December | 21 14 2 | |
| Interest on Post Office Savings Bank Account | 16 7 6 | |
| | | 207 15 0 |
| | | £8,888 18 4 |

## *Account*

PAID

| | £ s. d. | £ s. d. |
|---|---|---|
| Assistant Secretary: Salary ... ... ... ... ... ... ... ... £266 8 0 | | |
| Inland Revenue: Income Tax on ditto ... ... ... ... ... ... ... ... 83 12 0 | | |
| | 350 0 0 | |
| Assistant Secretary: Pension Premium (Society's Contribution £35; Assistant Secretary's Contribution £17, 10s.) ... ... ... ... ... ... ... ... | 52 10 0 | |
| Health and Unemployment Insurance ... ... ... ... ... | 3 18 0 | |
| Work done for London Mathematical Society, 1944 ... ... ... ... | 5 0 0 | |
| Clerical Assistance, including National Insurance ... ... ... ... ... ... | 90 14 3 | |
| Shorthand-typist: Salary ... ... ... ... ... ... ... ... £24 7 9 | | |
| Income Tax ... ... ... ... ... ... ... ... 3 5 0 | | |
| Health and Unemployment Insurance ... ... ... ... 0 12 9 | | |
| | 28 5 6 | |
| Porter and Wife: Wages and Cleaning ... ... ... ... ... ... ... £224 3 0 | | |
| Income Tax on ditto ... ... ... ... ... ... ... 4 3 0 | | |
| | 228 6 0 | |
| Pension Contribution ... ... ... ... ... ... ... ... ... | 13 0 0 | |
| Health and Unemployment Insurance ... ... ... ... ... ... | 6 14 4 | |
| | | 778 8 1 |
| Insurance ... ... ... ... ... ... ... ... ... ... ... ... ... | 18 5 1 | |
| Telephone ... ... ... ... ... ... ... ... ... ... ... ... ... | 20 11 11 | |
| | | 38 17 0 |
| Printing, etc.:— | | |
| *Monthly Notices* (Vol. **104**, Nos. 5, 6; Vol. **105**, Nos. 1–4) ... ... ... ... ... | 783 7 4 | |
| *Geophysical Supplement*, Vol. **5**, No. 4 ... ... ... ... ... ... ... ... | 19 9 9 | |
| Reprints ... ... ... ... ... ... ... ... ... ... ... ... ... | 45 19 3 | |
| Miscellaneous ... ... ... ... ... ... ... ... ... ... ... ... | 32 7 11 | |
| Photo-engraving ... ... ... ... ... ... ... ... ... ... ... ... | 53 15 1 | |
| | | 934 19 4 |
| Postages and Packing:— | | |
| Distribution of *Observatory* (recoverable) ... ... ... ... ... ... ... ... | 4 16 5 | |
| *Monthly Notices*, etc. ... ... ... ... ... ... ... ... ... ... ... | 77 3 10 | |
| Office Postages... ... ... ... ... ... ... ... ... ... ... ... | 54 0 7 | |
| | | 136 0 10 |
| A.R.P. Expenditure ... ... ... ... ... ... ... ... ... ... ... | 16 0 7 | |
| Stationery and Office Expenses ... ... ... ... ... ... ... ... ... ... | 86 17 7 | |
| Heating and Lighting ... ... ... ... ... ... ... ... ... ... ... | 141 19 8 | |
| Accountant's Fee ... ... ... ... ... ... ... ... ... ... ... ... | 21 0 0 | |
| Subscription to Committee on Library Co-operation ... ... ... ... ... ... ... | 1 1 0 | |
| Authorized Travelling Expenses, 1945 ... ... ... ... ... ... ... ... ... | 2 12 8 | |
| Repairs, Fittings and Fixtures ... ... ... ... ... ... ... ... ... ... | 96 6 7 | |
| House Expenses and Laundry ... ... ... ... ... ... ... ... ... ... | 20 7 2 | |
| Expenses of R.A.S. Meetings and Committees ... ... ... ... ... ... ... ... | 28 6 2 | |
| Miscellaneous Expenditure... ... ... ... ... ... ... ... ... ... ... | 21 7 9 | |
| Bank Charges and Cheque Books ... ... ... ... ... ... ... ... ... ... | 2 1 5 | |
| Library Expenses ... ... ... ... ... ... ... ... ... ... ... ... | 2 4 9 | |
| Gold Medal ... ... ... ... ... ... ... ... ... ... ... ... ... | 9 12 6 | |
| Reproduction of Presidential Portraits ... ... ... ... ... ... ... ... ... | 8 8 0 | |
| | | 458 5 10 |
| Purchase of Books from Potter Fund ... ... ... ... ... ... ... ... ... | | 13 9 6 |
| Headley Observatory:— | | |
| Rent of Observatory Paddock ... ... ... ... ... ... £5 0 0 | | |
| Insurance of Buildings and Instruments on Site ... ... ... ... 1 6 6 | | |
| Mr. Maskell for care of Site ... ... ... ... ... ... ... 0 13 0 | | |
| Repairs to Buildings ... ... ... ... ... ... ... ... 1 0 0 | | |
| Expenses moving Instruments ... ... ... ... ... ... ... 1 0 7 | | |
| | 9 0 1 | |
| *Less* Contribution from British Astronomical Association ... ... ... £2 12 6 | | |
| Contribution from Mrs. Phillips ... ... ... ... ... ... 0 7 6 | | |
| | 3 0 0 | |
| | | 6 0 1 |
| Block Subscription to *The Observatory* ... ... ... ... ... ... ... ... ... | | 110 0 0 |
| Lectures for the Forces:— | | |
| Lecturers' Travelling Expenses ... ... ... ... ... ... ... £3 7 0 | | |
| Porter's Attendance ... ... ... ... ... ... ... 1 10 0 | | |
| | 4 17 0 | |
| *Less* Contribution from British Astronomical Association ... ... ... ... ... | 2 8 6 | |
| | | 2 8 6 |
| | | 2,478 9 2 |
| Expenditure on Trust Accounts:— | | |
| Turnor and Horrocks Fund (Library) ... ... ... ... ... ... ... ... ... | 15 8 0 | |
| Harry Watson Fund ... ... ... ... ... ... ... ... ... ... ... | 11 19 2 | |
| George Darwin Lectureship Fund ... ... ... ... ... ... ... ... ... ... | 50 0 0 | |
| | | 77 7 2 |
| Balances, 1945 December 31:— | | |
| In hand of Assistant Secretary, on Petty Cash Account ... ... ... ... ... ... | 11 16 11 | |
| At Westminster Bank, on Current Account, as per Pass Book ... ... ... £698 7 10 | | |
| *Less* Cheques not yet presented... ... ... ... ... ... ... 229 19 3 | | |
| | 468 8 7 | |
| At Westminster Bank, on "B" Account (A. S. Williams Bequest) ... ... ... ... | 52 10 0 | |
| At Westminster Bank, on "C" Account:— | | |
| Trust Funds ... ... ... ... ... ... ... ... ... £368 16 10 | | |
| Sales of Duplicate Books Fund... ... ... ... ... ... ... 1 3 8 | | |
| | 370 0 6 | |
| At Post Office Savings Bank:— | | |
| General Fund (including £500 deposited 1945) ... ... ... ... 2,704 18 6 | | |
| "C" Account ... ... ... ... ... ... ... ... ... 671 8 8 | | |
| Staff Pension Fund at 1944 December 31 ... ... ... £250 0 0 | | |
| *Add* Deposited in 1945 ... ... ... ... ... 100 0 0 | | |
| Interest 1945 ... ... ... ... ... ... 5 14 7 | | |
| | 355 14 7 | |
| At London Savings Bank:— | 3,732 1 9 | |
| Ordinary Department (including £250 A. S. Williams Bequest) ... ... £1,127 16 6 | | |
| Special Investments Department ... ... ... ... ... ... 570 7 9 | | |
| | 1,698 4 3 | |
| | | 6,333 2 0 |
| | | £8,888 18 4 |

*Dr.* *General Fund Revenue Account*

| | £ s. d. | £ s. d. |
|---|---|---|
| To Salaries and Wages, including Pension Premiums and National Insurance ... ... ... ... ... ... ... ... | | 665 3 10 |
| „ Clerical Assistance, including National Insurance ... ... ... | | 90 14 3 |
| „ Insurance and Telephone (after adjusting Reserves) ... ... | | 39 7 0 |
| „ Printing, etc. (after adjusting Reserves) ... ... ... ... | | 1,024 19 4 |
| „ Posting and Packing (after adjusting Reserves) ... ... ... | | 108 9 6 |
| „ *General Expenses* (*after adjusting Reserves*) :— | | |
| Stationery and Office Expenses ... ... ... ... ... | 88 17 7 | |
| Lighting and Heating ... ... ... ... ... ... | 131 19 8 | |
| Travelling Expenses ... ... ... ... ... ... | 2 12 8 | |
| Subscription to Committee on Library Co-operation ... ... | 1 1 0 | |
| Accountants' Fee ... ... ... ... ... ... ... | 21 0 0 | |
| A.R.P. and Fire Watchers' Expenses ... ... ... ... | 14 0 7 | |
| Gold Medal ... ... ... ... ... ... ... | 9 12 6 | |
| Reproduction of Presidential Portraits ... ... ... ... | 13 13 0 | |
| Repairs and Cleaning of Fittings and Fixtures... ... ... | 76 6 7 | |
| I.A.U. Telegram Service for War Years ... ... ... | 20 10 0 | |
| Sundries ... ... ... ... ... ... ... ... | 79 12 3 | |
| | | 459 5 10 |
| „ Block Subscription to *The Observatory* ... ... ... ... | | 110 0 0 |
| „ Purchase of Books from Potter Fund... ... ... ... ... | | 13 9 6 |
| „ Headley Observatory, Expenses *less* Refunds ... ... ... | | 6 0 1 |
| „ Lectures for the Forces, Expenses *less* Refunds ... ... ... | | 2 8 6 |
| „ Annual Reserve for Repairs ... ... ... ... ... ... | | 40 0 0 |
| „ Reserve for Binding War-time Periodicals ... ... ... ... | | 100 0 0 |
| „ Staff Pension Fund: Amount set aside for year ... ... ... | | 100 0 0 |
| „ Net Revenue one year to date transferred to Balance Sheet... ... | | 71 10 10 |
| | | £2,831 8 8 |

*One Year to 1945 December 31* *Cr.*

| | £ s. d. | £ s. d. | £ s. d. |
|---|---|---|---|
| By *Amounts received from Fellows, viz.:—* | | | |
| 1 Arrear for 1922–24, written off and now repaid ... ... ... ... ... | 6 6 0 | | |
| 4 Arrears for 1940 ... ... ... ... | 8 8 0 | | |
| 6 „ „ 1941 ... ... ... ... | 12 12 0 | | |
| 9 „ „ 1942 ... ... ... ... | 18 18 0 | | |
| 9 „ „ 1943 ... ... ... ... | 18 18 0 | | |
| 23 „ „ 1944 (including 1 Institutional Membership Fee) ... | 48 6 0 | | |
| 1 Arrear, Admission Fee, 1940 ... ... | 2 2 0 | | |
| 3 Arrears, Admission Fees, 1944 ... ... | 6 6 0 | | |
| 2 „ First Contributions, 1944 ... ... | 2 2 0 | | |
| 488½ Annual Contributions for 1945 (including 10 from Fellows deceased, and £1, 2s. to complete Contribution) ... ... ... | 1,026 19 0 | | |
| 4 Institutional Membership Fees ... ... | 8 8 0 | | |
| 34½ Prepayments for 1945 (and £1 Part Contribution) ... ... ... ... ... | 73 9 0 | | |
| 42 Admission Fees ... ... ... ... | 88 4 0 | | |
| 39 First Contributions ... ... ... ... | 74 11 0 | | |
| | | 1,395 9 0 | |
| *Composition Fees:—* | | | |
| Initial Fees ... ... ... ... ... | 157 10 0 | | |
| Reduced Fees (including 2 guineas prepaid in 1944) ... ... ... ... | 326 11 0 | | |
| | 484 1 0 | | |
| *Less* Transferred to Reserve Account ... | 484 1 0 | | |
| | – – – | | |
| *Add* Amount brought to Credit for the year | 86 12 0 | | |
| | | 86 12 0 | |
| | | | 1,482 1 0 |
| „ Interest and Dividends received (gross) ... ... ... ... | | 864 5 8 | |
| „ Interest on Bank Deposit Accounts received ... ... ... | | 105 13 10 | |
| | | | 969 19 6 |
| „ Sales of Publications, Photographs and Miscellaneous Receipts for the year ... ... ... ... ... ... ... ... | | | 379 8 2 |
| | | | £2,831 8 8 |

*Note.—Fellows' 1945 Contributions not received were:—*

| | |
|---|---|
| 49 Unobtainable under War conditions ... ... ... | £102 18 0 |
| 27 Waived under Bye-law 26A ... ... ... ... ... | 56 14 0 |
| 13 Waived under Bye-law 26B ... ... ... ... ... | 27 6 0 |
| 22 Others unpaid at 1945 December 31 ... ... ... | 46 4 0 |
| 7 Admission Fees and First Contributions, ditto ... ... | 23 2 0 |
| 1 Institutional Membership Fee, ditto ... ... ... | 2 2 0 |
| Total for the year | £258 6 0 |

This amount has been added to the Suspense Account and is not included in this Revenue Account.

*Balance Sheet*

## LIABILITIES

| | £ s. d. | £ s. d. |
|---|---|---|
| 1 Contribution for 1946, paid in 1944 | 2 2 0 | |
| 26 Contributions for 1946, paid in 1945 | 54 12 0 | |
| 2 „ „ 1947, paid in 1945 | 4 4 0 | |
| 1 Contribution for 1948, paid in 1945 | 2 2 0 | |
| Part Contribution for 1949, paid in 1945 | 1 12 0 | |
| | | 64 12 0 |
| Sundry Creditors for Accounts due but not presented | | 518 0 10 |
| *Reserve for Repairs and Maintenance:—* | | |
| As at 1944 December 31 | 160 0 0 | |
| *Add* Set aside for 1945 | 40 0 0 | |
| | | 200 0 0 |
| *Reserve for Replacements of Photographic Slides and Prints:—* | | |
| As at 1944 December 31 | | 195 7 8 |
| *Reserve for Binding War-time Periodicals:—* | | |
| Amount set aside in 1945 | | 100 0 0 |
| *Trust Funds:—* | | |
| Capital as at 1944 December 31 | 5,207 0 3 | |
| Income Balances at 1945 December 31 | 1,039 15 1 | |
| Income Tax on Trust Funds, 1945 April–December, not yet refunded | 21 14 2 | |
| | | 6,268 9 6 |
| *Sales of Duplicate Books Fund:—* | | |
| As at 1944 December 31 | | 1 14 1 |
| *Composition Fees Reserve Fund:—* | | |
| As at 1944 December 31 | 959 6 8 | |
| Received in 1945 (including 2 guineas prepaid) | 484 1 0 | |
| | 1,443 7 8 | |
| *Less* 6% transferred to Current Account | 86 12 0 | |
| | | 1,356 15 8 |
| Advance Receipts for Publications, 1946 | 24 8 0 | |
| Advance Receipts for Postages, 1946 | 2 12 6 | |
| | | 27 0 6 |
| Credits still in hand from 1939 | | 0 10 11 |
| *Staff Pension Fund:—* | | |
| As at 1944 December 31 | 250 0 0 | |
| *Add* Amount set aside in 1945 | 100 0 0 | |
| Interest for year 1945 | 5 14 7 | |
| | | 355 14 7 |
| *General Fund:—* | | |
| As at 1944 December 31 | 22,972 15 7 | |
| *Add* Excess of Revenue over Expenditure, 1945 | 71 10 10 | |
| | | 23,044 6 5 |
| | | £32,132 12 2 |

*To the Fellows of THE ROYAL ASTRONOMICAL SOCIETY.*

We have examined the above Balance Sheet with the Books and Vouchers relating thereto explanations given to us.

We have verified the Securities representing the Investments and have found them to be

1945 *December* 31

ASSETS

| | £ s. d. | £ s. d. |
|---|---|---|
| Sundry Debtors, 1945 ... ... ... ... ... ... ... | | 49 19 0 |
| *Investments of General Fund*, valued as at 1922 December 29 or subsequent cost ... ... ... ... ... ... | | 20,374 11 1 |
| *Investments of Trust Funds*, valued at cost ... ... ... ... | | 5,207 0 3 |
| *Income Tax*, 1945 April–December, deducted at source, not yet refunded:— | | |
| General Fund ... ... ... ... ... ... ... | 146 5 8 | |
| Trust Funds ... ... ... ... ... ... ... | 21 14 2 | |
| | | 167 19 10 |
| Sundry Balances, as per Cash Account ... ... ... ... | | 6,333 2 0 |
| | | £32,132 12 2 |

*Note.—Fellows' Contributions (including 1 Institutional Membership Fee) and 7 Admission Fees unpaid at 1945 December 31: £1038, 9s. 0d. This amount represents the total of the Suspense Account and is not included in this Balance Sheet.*

and certify it to be correctly drawn up therefrom and in accordance with the information and in order.

SUFFOLK HOUSE,
5 LAURENCE POUNTNEY HILL, LONDON, E.C. 4,
1946 January 28

SHARP, PARSONS & CO.,
*Chartered Accountants.*

INVESTMENTS

As at 1945 December 31

*General Fund*

£2000 Swansea Corporation 3½ per cent. Stock.
£5125 London, Midland and Scottish Railway 4 per cent. Debenture Stock.*
£750 London, Midland and Scottish Railway 4 per cent. Preference Stock.*
£2400 Gas Light and Coke Co. 3 per cent. Consolidated Debenture Stock.*
£2000 Commercial Gas Co. 3 per cent. Debenture Stock.*
£496 Consolidated 4 per cent. Stock, 1957.
£1035 Agricultural Mortgage Corporation, Ltd., 4½ per cent. Debenture Stock, 1961–91.*
£1000 Hull Corporation 4½ per cent. Redeemable Stock, 1952–72.
£1000 Central Electricity Board 4½ per cent. Stock, 1957–82.*
£700 Birmingham Corporation 3 per cent. Inscribed Stock, 1947.
£2280, 5*s.* 3*d.* War Loan 3½ per cent. Inscribed Stock.
£500 New South Wales 4 per cent. Stock, 1942–62.*
£1156, 1*s.* 5*d.* Metropolitan Water Board 3 per cent. "B" Stock.
£500 National Defence Loan, 1954–58, 3 per cent. Bonds.
£500 National War Bonds 2½ per cent., 1946–48.
£2118, 3*s.* 5*d.* Savings Bonds 3 per cent., 1960/1970. (A Holding.)
£695, 16*s.* 0*d.* Conversion Loan 3½ per cent., 1961.

*Trust Funds*

£1004 Consolidated 4 per cent. Stock, 1957.
£965 Agricultural Mortgage Corporation, Ltd., 4½ per cent. Debenture Stock, 1961–91.*
£491, 10*s.* War Loan 3½ per cent. Inscribed Stock.
£1160, 16*s.* 3*d.* War Loan 3½ per cent. Inscribed Stock.
£542, 18*s.* 2*d.* Savings Bonds 3 per cent., 1960/1970. (B Holding.)
£1122, 19*s.* 6*d.* Savings Bonds 3 per cent., 1960/1970. (C Holding.)

* *Taxed at source.*

GIFTS TO THE GENERAL FUNDS AND PROPERTY OF THE SOCIETY

*The John Lee Gift :* In 1836 John Lee, Esq., LL.D., gave the Advowson of the living of Hartwell; in 1844 he gave the Advowson of the living of Stone, Bucks. In 1879 these Advowsons were repurchased by his heir, Edward Lee, Esq., for £700.

*The Lawson Bequest* (1856): Henry Lawson, Esq., bequeathed to the Society the sum of £200, free of legacy duty.

*The Carrington Bequest* (1876): R. C. Carrington, Esq., F.R.S., bequeathed to the Society £2000 Consols.

*The Lambert Bequest* (1877): C. J. Lambert, Esq., presented to the Society the sum of £500 free of legacy duty, being part of a sum of money bequeathed by his father, Charles Lambert, Esq., for scientific purposes.

*The McClean Bequest* (1905): Frank McClean, Esq., LL.D., F.R.S., bequeathed to the Society the sum of £2000, free of legacy duty.

*The Farrar Bequest* (1906): The Rev. A. S. Farrar, D.D., bequeathed to the Society the sum of £100, free of legacy duty.

*The Parsons Gift* (1922): The Hon. Sir Charles Parsons, K.C.B., F.R.S., gave to the Society £2500 War Stock 1929–47, in memory of his father, the 3rd Earl of Rosse, who made the 6-foot reflector, and who died 1867 October 31.

*The Grove-Hills Bequest* (1922): Colonel E. H. Grove-Hills, C.M.G., F.R.S., bequeathed to the Society, free of legacy duty, his collection of early astronomical and mathematical books up to the year 1700, together with a sum of £250 to cover the expenses incurred by the Society in connection with the books.

*The Grove-Hills Fund* (1922): In 1922 the Treasurer, Colonel Grove-Hills, collected by his private efforts, with the approval of the Council, a Special Fund to meet the immediate financial difficulties of the Society. The total amount received from all sources (including dividends on the investments representing the fund) was £1913, 1*s.* 11*d.*, of which £1480, 2*s.* 10*d.* was invested and is now represented by £535 Agricultural Mortgage 4½ per cent., £423, 15*s.* 11*d.* War Stock 3½ per cent., and £695, 16*s.* Conversion Loan 3½ per cent. 1961.

*The Lindemann Bequest* (1931): A. F. Lindemann, Esq., bequeathed to the Society the sum of £1000, free of legacy duty.

*The Archdeacon Potter Bequest* (1933) (*see below*).

*The Goodridge Bequest* (1936): Captain J. J. L. Goodridge, who died 1936 March 13, bequeathed to the Society the sum of £50, free of legacy duty. In 1937 the bequest was invested in £49, 0*s.* 4*d.* War Stock 3½ per cent.

*The Herbert Spencer Bequest* (1936): Herbert Spencer, Esq., who died in 1903, nominated the Royal Astronomical Society as one of twelve Learned Societies to be eventual beneficiaries of his residuary estate. His estate was wound up in 1936, and the Society's share of the residue amounted to £1241. The conditions of acceptance of the legacy were that the sum received should be spent in certain specified ways by the Governing Body within five years of the date of payment, and might not be used in any way for purposes of endowment. The bequest was finally expended during 1941.

*The Lindley Bequest* (1937): Miss Julia Lindley bequeathed to the Society the sum of £1000, free of legacy duty, which was received from the Public Trustee in the form of £1156, 1*s*. 5*d*. Metropolitan Water Board 3 per cent. "B" Stock.

*The Stanley Williams Bequest* (1939): A. Stanley Williams, Esq., who died 1938 November 21, bequeathed to the Society all his astronomical instruments, books, maps, photographs, manuscripts, etc., together with the sum of £200, free of legacy duty, for the reduction or publication of his observations of variable stars; and also a further sum of £100, free of legacy duty, for the furtherance of astronomy in general or of the Society in particular, in such manner as the Council of the Society may think fit. No expenditure from the fund has been made up to 1945 December 31.

SPECIAL FUND

*The Archdeacon Potter Fund* (1933): Archdeacon Beresford Potter, who died 1931 May 10, bequeathed to the Society a 3/88th share of his residuary estate. This legacy was received in 1933, and now stands invested in £300 3½ per cent. War Stock, the cash balance of £17, 15*s*. 2*d*. being expended on the library in 1934. The Council resolved to allocate the dividends from this fund for the purposes of the library.

| | £ | *s*. | *d*. | | £ | *s*. | *d*. |
|---|---|---|---|---|---|---|---|
| 1945 Jan. 1. Balance of Fund ... | 51 | 5 | 1 | 1945. Purchase of Books ... | 13 | 9 | 6 |
| 1945. Dividends, War Stock 3½ per cent. ... ... ... | 10 | 10 | 0 | 1945 Dec. 31. Balance of Fund | 48 | 5 | 7 |
| | £61 | 15 | 1 | | £61 | 15 | 1 |

TRUST FUNDS

*The Lee and Janson Fund* (1834 and 1879): In 1834 John Lee, Esq., LL.D., gave £100, and in 1879 T. C. Janson, Esq., bequeathed £200, the interest to be given to the widow or orphan of a deceased Fellow. These amounts now stand in £309, 16*s*. 3 per cent. Savings Bonds, 1960/1970.

| | £ | *s*. | *d*. | | £ | *s*. | *d* |
|---|---|---|---|---|---|---|---|
| 1945 Jan. 1. Balance of Fund ... | 49 | 16 | 1 | 1945 Dec. 31. Balance of Fund:— | | | |
| 1945. Dividends, 3 per cent. Savings Bonds ... ... | 9 | 6 | 0 | In P.O. Savings Bank ... ... £36 10 8 | | | |
| Interest on P.O. Savings Bank Deposit ... ... ... | 0 | 18 | 1 | At Bank ... ... 23 9 6 | 60 | 0 | 2 |
| | £60 | 0 | 2 | | £60 | 0 | 2 |

*The Turnor Fund and the Horrocks Memorial Fund* (1853 and 1876): In 1853 the Rev. Charles Turnor, M.A., bequeathed a sum of £500, which now stands in £430, 10*s.* 4*d.* 3 per cent. Savings Bonds, 1960/1970. In 1876 the Society received a sum of £38, 15*s.*, the unexpended balance of a fund collected for the purpose of erecting a memorial in Westminster Abbey to Jeremiah Horrocks: to this the Society added the sum of £55, 15*s.*, and the whole now stands in £95, 13*s.* 2*d.* 3 per cent. Savings Bonds, 1960/1970. The interest on these funds is to be used in the purchase of books for the library.

| | £ | *s.* | *d.* | | £ | *s.* | *d.* |
|---|---|---|---|---|---|---|---|
| 1945 Jan. 1. Balance of Fund ... | 4 | 5 | 8 | 1945. Purchase of Books ... | 15 | 8 | 0 |
| 1945. Dividends, 3 per cent. Savings Bonds ... ... | 15 | 15 | 8 | 1945 Dec. 31. Balance of Fund... | 4 | 13 | 4 |
| | £20 | 1 | 4 | | £20 | 1 | 4 |

*The Hannah Jackson* (*née Gwilt*) *Fund* (1861): In 1861 Mrs. Hannah Jackson (*née* Gwilt) gave £300 Consols, which now stands in £287 3 per cent. Savings Bonds, 1960/1970; the interest to be given in medals or other awards in accordance with the terms of the Trust.

| | £ | *s.* | *d.* | | £ | *s.* | *d.* |
|---|---|---|---|---|---|---|---|
| 1945 Jan. 1. Balance of Fund ... | 38 | 5 | 3 | 1945 Dec. 31. Balance of Fund... | 46 | 17 | 3 |
| 1945. Dividends, 3 per cent. Savings Bonds ... ... | 8 | 12 | 0 | | | | |
| | £46 | 17 | 3 | | £46 | 17 | 3 |

*The Harry Watson Memorial Fund* (1923): In 1920 Mrs. Watson presented to the Society the sum of £300 as a memorial to her late husband, Lieut.-Col. Harry James Watson, F.R.A.S., the interest on this sum to be used for the purchase of books for the library, such books to be indicated by a special book-plate. This gift now stands invested in £542, 18*s.* 2*d.* 3 per cent. Savings Bonds, 1960/1970. In 1923 Mrs. Watson bequeathed a further sum of £958, 17*s.* to the Society, which now stands invested in £965 Agricultural Mortgage 4½ per cent. Stock. The Council resolved that these two sums should together constitute a Trust Fund, to be designated *The Harry Watson Memorial Fund*, to be used for the purchase and binding of books.

| | £ | *s.* | *d.* | | £ | *s.* | *d.* |
|---|---|---|---|---|---|---|---|
| 1945 Jan. 1. Balance of Fund ... | 311 | 16 | 3 | 1945. Purchase of Books ... | 11 | 19 | 2 |
| 1945. Dividends, Agricultural Mortgage 4½ per cent. ... | 21 | 14 | 4 | 1944 Dec. 31. Balance of Fund:— | | | |
| Dividends, 3 per cent. Savings Bonds ... ... ... ... | 16 | 5 | 8 | In P.O. Savings Bank ... ... £233 15 6 | | | |
| Income Tax, 1944 April–1945 April, refunded ... ... | 21 | 14 | 2 | At Bank ... ... 131 9 9 | | | |
| Interest on P.O. Savings Bank Deposit ... ... ... | 5 | 14 | 0 | | 365 | 5 | 3 |
| | £377 | 4 | 5 | | £377 | 4 | 5 |

*The George Darwin Lectureship Fund* (1926): In 1926 Sir James Jeans presented to the Society the sum of £1000 for the endowment of an annual lectureship, to be called *The George Darwin Lectureship*, the lecture to be on some subject of interest to astronomers, preference being given, in electing a lecturer, to one normally resident outside the British Isles.

This sum now stands in £1004 Consolidated 4 per cent. Loan. The income is annually applied to the purposes of the Trust in accordance with the terms of the Deed of Gift.

| | £ | s. | d. | | £ | s. | d. |
|---|---|---|---|---|---|---|---|
| 1945 Jan. 1. Balance of Fund ... | 147 | 13 | 5 | 1945 Oct. Lecture Fee ... ... | 50 | 0 | 0 |
| 1945. Dividends, Consolidated 4 per cent. Loan ... ... | 40 | 3 | 2 | 1945 Dec. 31. Balance of Fund:— In P.O. Savings Bank ... ... £129 16 2 | | | |
| Interest on P.O. Savings Bank Deposit ... ... ... | 3 | 3 | 4 | At Bank ... ... 11 3 9 | | | |
| | | | | | 140 | 19 | 11 |
| | £190 | 19 | 11 | | £190 | 19 | 11 |

*The A. G. Stillhamer Trust* (1937): A. G. Stillhamer, Esq., of Bloomington, Illinois, left all his property outright to Miss Maude S. Capps, of Bloomington; but on account of certain personal memoranda and conversation between Mr. Stillhamer and Miss Capps, the latter resolved to carry out what she believed to have been Mr. Stillhamer's wishes by the payment to the Royal Astronomical Society of the sum of 2500 dollars in cash, the conditions of acceptance being that the principal is to remain intact in the endowment fund of the Society, and the income therefrom to be used annually * to pay expenses of scientific research or to purchase definite scientific instruments for use in scientific instruction or research. The bequest has been invested in £491, 10*s.* War Stock 3½ per cent.

| | £ | s. | d. | | £ | s. | d. |
|---|---|---|---|---|---|---|---|
| 1945 Jan. 1. Balance of Fund ... | 125 | 6 | 8 | 1945 Dec. 31. Balance of Fund:— In P.O. Savings Bank ... ... £97 16 5 | | | |
| 1945. Dividends, War Stock 3½ per cent. ... ... ... | 17 | 4 | 0 | At Bank ... ... 47 2 0 | | | |
| Interest on P.O. Savings Bank Deposit ... ... ... | 2 | 7 | 9 | | 144 | 18 | 5 |
| | £144 | 18 | 5 | | £144 | 18 | 5 |

*The E. W. Brown Trust* (1939): E. W. Brown, Esq., M.A., Sc.D., F.R.S., who died in 1938, bequeathed to the Society the sum of five thousand dollars, and desired that the income from the bequest should be used for assistance in the calculation of accurate orbits of the bodies of the solar system, such income as should not be used for this purpose being used for the general purposes of the Society. The bequest was received in 1939 July, and was invested in £1160, 16*s.* 3*d.* War Stock 3½ per cent.

| | £ | s. | d. | | £ | s. | d. |
|---|---|---|---|---|---|---|---|
| 1945 Jan. 1. Balance of Fund ... | 232 | 3 | 11 | 1945 Dec. 31. Balance of Fund:— In P.O. Savings Bank ... ... £172 19 6 | | | |
| 1945. Dividends, War Stock 3½ per cent. ... ... ... | 40 | 12 | 6 | At Bank ... ... 104 1 3 | | | |
| Interest on P.O. Savings Bank Deposit ... ... ... | 4 | 4 | 4 | | 277 | 0 | 9 |
| | £277 | 0 | 9 | | £277 | 0 | 9 |

* Miss Capps, subsequently to the initial conditions of the Trust, agreed to the income not being expended annually.

LIST OF PUBLIC INSTITUTIONS AND OF PERSONS WHO HAVE PRESENTED GIFTS (OTHER THAN BY EXCHANGE) TO THE LIBRARY DURING THE YEAR 1945

Aarhus, Ole Rømer Observatoriet
Algiers, Observatoire
Astronomical Society of Mexico
Astronomical Society of South Africa
Astronomical Society of Tasmania
British Council
Chinese Astronomical Society
Chinese Physical Society
Committee for the Continued Distribution of Astronomical Literature, Harvard College Observatory
Copenhagen, Nordisk Astronomisk Selskab
Erevan, Astronomical Observatory
Griffith Observatory, Los Angeles
Helsinki, Finnisches Geodätisches Institut
Imperial Chemical Industries
International Astronomical Union
Kirkwood Observatory of Indiana University
Le Houga (Gers), Observatoire
Lourenço Marques, Technical Statistical Department
Madrid, Asociacion Espanola para el Progresso de las Ciencias
New York, Academy of Sciences
Paris, Institut d'Astrophysique
Paris, Observatoire
The Royal Canadian Air Force
The Royal Society
Society for Research on Meteorites
H.M. Stationery Office
Strasbourg, Institut de Physique du Globe
Tashkent Astronomical Observatory
The Technical Press Ltd.
University of California
Washington, Carnegie Institution
Washington, National Bureau of Standards

Professor H. Alfvén
The late Mr. A. C. Allen
Dr. G. Alter
Mr. E. A. Beet
Mr. C. E. R. Bruce
Dr. P. ten Bruggencate
Dr. H. P. Coster
Mr. P. Councel
Dr. A. K. Das
Professor H. Dingle
Wing Commander R. S. J. Edwards
Mme Flammarion
Dr. W. Gleissberg
Mrs. Goodman
The late Mr. A. R. Hinks
Dr. L. T. Houa
Mr. G. Jarnefelt
Sir Harold Spencer Jones
Monsieur V. Kourganoff
Mr. P. C. Leonard
Dr. A. O. Leuschner
Mr. A. Löw
Dr. G. C. McVittie
Mr. K. G. Meldahl
Professor E. A. Milne
Professor M. Minnaert
Mr. R. D. Perry
Professor H. C. Plummer
Professor H. Shapley
Mr. John Q. Stewart
Monsieur N. Stoyko
Professor Elis Strömgren
Dr. J. Tuominen
Professor A. Unsöld
Monsieur G. de Vaucouleurs
Dr. M. Waldmeier

## OBITUARY NOTICES.

HUGH LANCELOT ALDIS was born in Calcutta on 1870 August 26, being the eldest of a family of nine children. At the age of five he was sent home from India to England, where later on his father was appointed headmaster of Queen Mary's School, Walsall. At the age of thirteen, while attending Queen Mary's School, Walsall, he gained a scholarship to the City of London School.

His father and two of his uncles had graduated from Trinity College, Cambridge, as respectively sixth wrangler, senior wrangler and second wrangler. It was not surprising, therefore, that he should himself have shown early promise of mathematical ability and gone to Trinity College, Cambridge, in 1889, where he studied for the mathematical tripos.

It was as an undergraduate at Trinity College that his keen interest in astronomy was first aroused, and at the age of twenty he determined to make his own reflecting telescope. For this great effort he used two 6-inch diameter glass disks, kindly given by Messrs. Chance Brothers, two line props screwed together to act as a trammel with which to cut a circular template, a bradawl specially ground on the doorstep to a suitable cutting edge, and an old apple-barrel filled with bricks as a rigid post.

After taking great pains in the final figuring of the reflector and the careful polishing of the 45° small mirror (the Newtonian type of reflector having been adopted), and using an eyepiece borrowed from his father's microscope, he had the immense satisfaction of seeing, on a clear night, both Saturn's rings and Jupiter's moons admirably defined.

There is little doubt that at about this time his interest in astronomy and mathematical optics rather deflected his energies from what his parents had set their hearts on, namely his attaining a good position amongst the first ten wranglers, so that when, in 1892, he came out as fourteenth wrangler they were genuinely disappointed. He himself, however, was extremely contemptuous of the geometrical optics then taught at Cambridge, and had no ambitions to make himself an adept at quickly solving the ingenious little mathematical puzzles with which the examiners sought to test the abilities of the tripos candidates in those days.

On going down from Cambridge he was appointed to a position on the scientific staff of Messrs. J. H. Dallmeyer, Ltd., where he threw himself heart and soul into the task of mastering the design of photographic lenses, using mathematical formulæ of his own devising.

In 1896 he was made a Fellow of the Royal Astronomical Society, and this year saw the fruits of his labours in the introduction of the well-known series of anastigmat lenses known as "The Dallmeyer Stigmatic". By the use of the so-called Jena glasses and his own methods of mathematical computation he was able to produce an $f/4$ portrait lens giving very good corrections over a total angle of 60°.

A later variant of this "Stigmatic" lens, known as the "Series 3", curiously enough completely anticipated the Zeiss-Tessar patent. Nobody seems to have noticed this at the time, and it remained for several years one of the amazing secrets in the optical world.

He married Violet Atkinson, daughter of Dr. Atkinson, of Surbiton, in 1900, and shortly afterwards, in 1901, he left Messrs. Dallmeyer and, joining his younger brother in Birmingham, founded the firm of Aldis Brothers at Sparkhill.

In the previous year he had read a paper before the Royal Photographic Society on the construction of photographic objectives, in which he had shown how the problem of satisfying the conditions for a fully corrected anastigmat lens could to a certain extent be compared with the problem of ensuring the equilibrium of a system of parallel forces, and he demonstrated that there were no theoretical reasons why anastigmat lenses should not be greatly simplified.

After the formation of the new partnership he realised his great ambition, and brought out the simple form of anastigmat bearing his name, involving a cemented combination placed in front of a single simple lens. This became known all over the world as "The Aldis Lens".

In 1908, after the accident to the submarine A1, involving the loss of eleven lives, he was successful in designing a model of a submarine periscope giving a view all round the horizon in one image. At the time it was thought that this would be instrumental in preventing any recurrence of such tragedies.

In 1912, knowing how completely he had anticipated the Zeiss-Tessar patent, he boldly brought out the well-known Aldis $f/4{\cdot}5$ lens, which was an infringement of that patent. Only after many thousand Aldis $f/4{\cdot}5$ lenses had been sold did the firm of Zeiss discover that their patent had been infringed, but in view of the manifest anticipation by the Series 3 lens mentioned above, the legal proceedings completely broke down, and nothing more was heard of any Zeiss opposition after the 1914–18 war. During that war he designed a telescopic rifle sight and an important invention known as "The Aldis Unit Sight", in which he was the first to realise the important optical results obtained by four co-axial equal objectives each placed in telescopic adjustment with its adjacent element. Such a telescope gives the effect of looking through an empty napkin-ring, and this was found to be the ideal sight for aiming the fixed gun in fighting aeroplanes.

He also designed a very good 20-inch $f/5{\cdot}6$ anastigmat for aerial reconnaissance work, and later a Camera Aiming Sight having "eye freedom", which was such a useful feature of the well-known Aldis Unit Sight. After the 1914–18 war the Solar Physics Observatory purchased an $f/4{\cdot}5$ long-focus lens of his own design.

He retired in 1938 from the firm that he had founded, and lived at his home at Lyme Regis, Dorset, until his death, on 1945 July 18, after a very short and quite unexpected illness, leaving a widow, two sons and a daughter.

A. C. W. ALDIS.

ASHTON CHARLES ALLEN was born in London on 1859 January 6, and died at Shillingford, Oxford, on 1945 April 27. Until the end of the first world war he travelled about a great deal, finally making his home in Folkestone, where he lived until the second world war forced him to leave in 1940.

He was always very interested in astronomy, and also in meteorology and naval history. With his daughter he went to Algiers for the total eclipse of the Sun in 1900, to Palma in Africa for the 1905 eclipse, to Paris in 1911, and to Southport for the 1927 eclipse. He did some photographic work at the first of these eclipses, and also had his own telescope with which he observed until failing eyesight forced him to stop.

He is survived by one daughter.

Allen became a Fellow of the Society on 1902 January 10.

ROBERT BALLARD was born at Highbury in the year 1869, and was the youngest son of Dr. Edward Ballard, F.R.S. He was educated at Hurstpierpoint College, and later trained at St. Bartholomew's Hospital, qualifying in 1893 M.R.C.S. (Eng.) and L.R.C.P. (Lond.).

In 1900 he joined Dr. Tyndall at Market Harborough and rendered valuable medical services in that district for thirty-five years, when he returned to London and resided at 78 Redcliffe Gardens until his death.

He was Senior Clinical Assistant at the Royal Westminster Ophthalmic Hospital; Hon. Medical Referee British Home for Incurables; Hon. Medical Referee Royal National Hospital for Consumption; and a Medical Referee to the Ministry of Pensions.

He was elected a Fellow of the Society on 1927 February 11, and, in addition to some practical observing, he found pleasure in reading and discussing the writings of our foremost men of science.

Robert Ballard was a kindly and upright man, beloved by those who knew him.

In 1900 he married Beatrice Combe of Chester, and there are four children, a son and three daughters. His wife died in 1935.

Ballard bore with courage and cheerfulness a year of increasing pain and weakness, and died on 1945 July 30. He is sadly missed by his family, his friends, and by many who had been his patients.

T. G. HIRST.

WILLIAM IRA BROWN, who died in 1944 December, studied Theology at the Scholae Episcopi in Manchester, and was ordained Deacon in 1912 and Priest in 1913. His first curacy was at St. Philip's, Bradford Road, Manchester, and in the first world war he was a Chaplain to the Forces.

His interest in astronomy was stimulated by his old vicar, the Rev. Canon L. Spencer Murdock, who was a keen astronomer and a friend of Sir Robert S. Ball. When Brown was appointed senior curate of Blackburn in 1920, he became acquainted with Father Rowland of Stonyhurst and was permitted to use the instruments there.

He was appointed vicar of Ribchester in 1924 and became rector in 1943. Owing to his personality and his numerous interests he made many warm friendships in Ribchester, where he gave many talks on astronomical subjects.

He was elected a Fellow of the Society on 1929 February 8.

JOHN EDMUND CALTHROP was born at Lincoln on 1891 July 18, and was educated at Lincoln Technical School. He proceeded to Borough Road Training College as a student teacher, returning to his old school as science master in 1913. He enlisted in the Honourable Artillery Company early in the first great war, and was wounded at Beaumont Hamel in 1916 November. On his recovery he was given a commission in the Royal Garrison Artillery, and he served in Flanders till 1918. After the war he went to Cambridge as an exhibitioner of Pembroke College, and he joined the staff of Queen Mary College, London, in 1921, subsequently becoming senior lecturer in Physics. He died on 1945 June 18.

Calthrop was a man of fine character, and his kindly disposition and personal charm won affectionate regard from colleagues and pupils alike, and gained for him a fresh circle of friends when Queen Mary College was evacuated to King's College, Cambridge, in 1939. The main concern of his life was his work as lecturer and tutor, to which he devoted much careful labour. He had a strong sympathy for young people, and he took an active interest in undergraduate pursuits and was treasurer of the College Students' Union.

Calthrop was first attracted to the study of astronomy, and especially of astrophysics, through his work as a lecturer in physics, but he also became interested in the history of astronomy, and one of his published papers is an account of the scientific relics of James Ferguson. He found his recreations chiefly in the theatre, and in reading Italian literature.

He became a Fellow of the Society on 1933 January 13.

G. S. LE BEAU.

WILLIAM ERNEST COOPER was born in Huddersfield on 1857 February 11, and died at Bentham, near Cheltenham, on 1945 March 16.

Cooper was a well-known jeweller in Worcester, where he was in business until after the 1914–18 war. He continued to live in Worcester after retiring from business until his sister, with whom he lived, died in 1929. After this he moved to Cheltenham, where, under the name of "Silver Fox", he gave generously to hospitals and other local charities.

Although blind for the last ten years of his life, he contrived to take a great interest in astronomical works and news which were read to him.

He became a Fellow of the Society on 1881 January 14.

JOHN EDMUND DROWER, son of George Marwood Drower of Torquay, was born on 1853 March 27 and died on 1945 January 18. He was privately educated and was originally intended for the Bar, but he became interested in surveying and finally adopted it as a profession. He worked with Sir Reginald Blomfield for many years and was surveyor for several important public buildings, including the Menin Gate. An outstanding achievement of his was the weighing of the dome of St. Paul's, which he accomplished alone in 1913 with nothing more than a foot-rule in the way of apparatus.

In 1915 Drower was invited to enter the War Office and became Assistant Director of Army Contracts. He also organised the Department of Building Materials Supply for the Ministry of Munitions, and became its first Director. After the Armistice of 1918 he was sent to Belgium to act as arbitrator in connection with reparations. He was made a C.B.E. in 1919.

When still a young man, Drower became acquainted with the late Dr. A. A. Common, who encouraged his already long-established interest in astronomy and provided him with a 6-inch equatorial refractor by Wray. This instrument he used himself until compelled by a serious illness to abandon night work; and some years later, with characteristic generosity, he presented it to a younger amateur, as he felt that it ought no longer to lie unused. Though forced to give up observing he never lost his interest in matters astronomical and, to within a few years of his death, was often to be seen at meetings of the Society and at Visitations of the Royal Observatory.

Drower was of a modest and self-effacing disposition, but the few who were privileged to know him at all intimately will remember him as a man of charming personality and wide knowledge, who could talk in an interesting way on a variety of subjects. He was well read in the literatures of France, Germany and Italy, and spoke the languages of these countries fluently. He was also no mean connoisseur of old china and of works of art in general.

He married Florence, daughter of Edwin Chivers of Tavistock, and is survived by a daughter and two sons.

He was elected a Fellow of the Society on 1888 April 13.

W. H. STEAVENSON.

ALEXANDER DAVIDSON FLEMING died on 1945 April 8 at the age of eighty-three. He spent his life in the service of the Scottish Widows' Fund and Life Assurance Society, starting as a junior in 1877 and, after various appointments in Birmingham and London, becoming Cashier at the Head Office in Edinburgh until his retirement after fifty-one years of service. He volunteered in the Boer War and was a Company Commander of the Royal Warwickshire Regiment, receiving the Queen's Medal. He also served in the war of 1914–18, retiring with the rank of Major.

His great interest in astronomy was shared with his father, the late Crawford Muir Fleming (*M.N.*, **92**, 252, 1932), and his uncle, the late Canon David Fleming (*M.N.*, **81**, 257, 1921). He had his own telescopes and could speak entertainingly about his hobby.

He was elected a Fellow on 1906 December 14.

WALTER FREDERICK GALE, who died suddenly at his home in Waverley, New South Wales, on 1945 June 1, was born on 1865 November 27. After a period of training in various commercial offices he joined the Savings Bank of New South Wales, afterwards the Government Savings Bank of New South Wales, and remained in its service for thirty-eight years, becoming manager of the Head Office. He retired in 1925, and spent some years as manager of the Hoskins Estate Company.

Although he attained success in his professional life he was much more widely known, popularly as well as among scientific people, as an amateur astronomer. His interest in astronomy began at an early age, and he always said that he did not remember the time when he did not know the constellations. He became an active amateur before he reached his twenties, and in 1886, when he was nineteen, he constructed a 7-inch reflecting telescope and continued the observational work which he had already begun with a small refractor. During his lifetime he owned more telescopes than pass through the hands of most astronomers, either professional or amateur, and made a number of the mirrors himself. In 1893 he made a tour, observing the eclipse of the Sun on April 16 in Chile with the party from the Lick Observatory, and visited many of the observatories in America and Europe; many of the contacts made at this time were maintained. Immediately on his return to Australia he became actively interested in the organisation of amateur astronomy, and was largely responsible for the formation, in 1894, of the New South Wales Branch of the British Astronomical Association. He was the first Secretary of the Branch, and his interest in it and his influence may be judged by the fact that on twenty-one occasions he was its President. In 1944 the Branch held a complimentary meeting to him on the occasion of the fiftieth anniversary of his membership of the Association, and the Association in London elected him to honorary membership. Another position in which he rendered valuable service to astronomy was as a member of the Board of Visitors of Sydney Observatory. He was on this Board for twenty-eight years, being its chairman at the time of his death.

During the whole of his lifetime he has been a most assiduous observer, always recording with care the observations he was making. He independently discovered seven comets, of which three (1894 *b*, 1912 *a* and 1927 *f*) bear his name. This alone is testimony to many patient hours spent at the telescope. His work as an observer of the planets Mars, Jupiter and Saturn has been most extensive, and many drawings were published in the *Journal* and *Memoirs* of the British Astronomical Association. In 1892 he discovered several previously unobserved "canals" on Mars, and was the first to note the presence of the "oases". Several double stars which he discovered bear his name.

Gale was elected a Fellow of the Society in 1893, and was awarded the Jackson-Gwilt Medal in 1935 "for his discoveries of comets and his work for astronomy in New South Wales". His life was a very full and active one right to the end, and undoubtedly was greatly enriched by his pleasure in astronomy and his activity in the Astronomical Association, to which his death is a serious blow. He enjoyed the meetings of our Branch, which he very rarely missed during the whole of his more than fifty years of membership. His ready participation in discussion is something that will long be remembered. Only two days before his death he attended and actively participated in one of these meetings. He always took pleasure in giving advice and help to beginners, and promoted education in astronomy by many public lectures on the subject.

He is survived by his widow, two sons and four daughters.

H. WOOD.

ARTHUR ROBERT HINKS was born in London on 1873 May 26, and died at Royston on 1945 April 18. He studied at the Whitgift Grammar School, Croydon, and at Trinity College, Cambridge. In 1895 he was appointed Assistant at the Cambridge Observatory, and promoted to Chief Assistant in 1903, a position which he held for ten years. During this time he was active in developing photographic astrometry, following the then novel methods originated by Turner and Kapteyn. As early as 1902 he planned a campaign for photographic determinations of stellar parallax with the 12-inch Sheepshanks photovisual coudé. The writer—whose first introduction to the subject came from Hinks's lectures—was fortunate enough to have a large part in the execution of this plan, and can testify to the thoroughly modern character of the work, which was

conducted on principles almost exactly the same as those developed independently by Schlesinger at about the same time, which have served as the basis for all later work.

His own energy was already devoted in 1903 mainly to the determination of the solar parallax from the observations of Eros secured during the international campaign of 1901. Only one thoroughly familiar with the intricacies and pitfalls of the photographic method could have carried this laborious work to a successful conclusion. His final result published in the *Monthly Notices* for 1910, had a greater weight than all previous determinations, and, as a by-product, led to a correspondingly strong determination of the mass of the Moon. This admirable work was justly recognized by the award of the Gold Medal of our Society in 1912.

Only after thirty years has this value been superseded by Sir Harold Spencer Jones's discussion of the observation of Eros in 1930–31, when its parallax was almost twice as great as in 1901.

Hinks was not only a master of the theory and practice of photographic reductions; he was an excellent observer. Every detail of the Sheepshanks telescope, its mounting and the building in which it was installed, had his careful attention. He enjoyed telling how the architect, after he had protested about the presence of shiny brass handles inside the dark-room, turned on him saying, "Are you going to black your face when you look at the plate?"

The measuring-machine of the Cambridge Observatory was also largely of his design, and proved to be rapid and accurate in the measurement of plates provided with a réseau.

In 1913 he resigned his position at Cambridge, and was appointed Assistant Secretary of the Royal Geographical Society—succeeding to the Secretaryship two years later. The full story of his thirty years' distinguished service in this new field has been told elsewhere. He was a recognized authority on map projections, and his book bearing this title is a standard work. In recognition of his contributions to the preparation of military maps during the war of 1914–18 he was made a C.B.E. in 1920. He edited the *Geographical Journal* for many years, and his advice was of value to many travellers and explorers.

This gain to a sister-science was, however, a great loss to British astronomy. Hinks, more than anyone else in his generation, was the inheritor of the tradition of Turner, and his diversion to another field left work in this one to be done in other countries. As a Cambridge man, who has never lost the interest in photographic astronomy which he learned there, the writer may be pardoned for regretting that it was not continued there under so able a representative.

In addition to the honours already mentioned, Hinks was elected a Fellow of the Royal Society in 1912—while still an astronomer!—and received the Victoria Medal of the Royal Geographical Society in 1938 and the Cullum Medal of the American Geographical Society in 1942.

He was elected a Fellow of the Society on 1899 January 13, served on its Council from 1903 to 1913, as a Secretary from 1909 to 1912, and as a Vice-President from 1912 to 1913.

In 1899 he married Lily Mary Packman, who died in 1928. Two sons survive them.

Personally Hinks was a forthright Englishman, with frank and honest Tory convictions—in politics at least—which did not interfere with a wide circle of friendship. The writer cannot close these lines without an expression of gratitude to him and his wife for great kindness in his student days which, after a lapse of more than forty years, is keenly remembered.

H. N. RUSSELL.

JOHN ROBERT FISHER JEFFREYS was born on 1916 January 25. His untimely death has deprived the British astronomical world of a recruit whom it can ill afford to lose. He had a truly remarkable success as a teacher of students for the mathematical tripos. He became interested in astronomy in the michaelmas term of 1938. As a mathematician he followed astrophysical theory very closely, but Jeffreys preferred practical to theoretical research and was entirely happy with a soldering iron in his hand. He was prominent among the little band of amateurs who installed Dr. Steavenson's 30-inch telescope in the Observatory grounds and built the dome around it; but his main work in 1939 was his preparation for a programme of photo-electric work which it was hoped to carry out at the eclipse of 1940 October 1. At the outbreak of war Jeffreys threw up all his astronomical work. His health was never strong, but, had he lived, it is certain that he would have carried out observational work of outstanding value.

He was elected a Fellow of the Society on 1938 April 8.

R. V. D. R. WOOLLEY.

PETER KENNEDY, who died in South Australia on 1945 June 19, was a Fellow of this Society since 1936. For many years he had been a keen amateur student of astronomy, and was at one time Vice-President of the Astronomical Society of Western Australia. At the time of his death Kennedy was using a telescope of his own design. He was particularly interested in the Moon and the planets.

Kennedy was born on 1874 October 29, and was a son of the late Alexander Kennedy, Kingussie, Scotland. For forty-one years he was an officer of the Postmaster-General's Department of Australia. He entered the service in Victoria early in the 'nineties, went to Western Australia at the time of the Gold Rush and was Chief Operator for the Department at the goldfields in 1896.

Apart from his interest in astronomy, Kennedy devoted much time to the study of telephony and broadcasting. He was appointed Assistant Engineer, Postal Department, Perth, in 1908, State Engineer for Western Australia, 1918, for South Australia, 1926, and for New South Wales, 1933. He was appointed Deputy Director, Posts and Telegraphs, South Australia, in 1934, and was awarded the Imperial Service Order and the Coronation Medal prior to his retirement from that position in 1937 July.

In 1900 June Kennedy married Ettie Hutchinson, elder daughter of William Hutchinson of "Yarraholm", Warrandyte, Victoria. There are two daughters.

M. KENNEDY.

EDWARD AYEARST REEVES was born on 1862 February 9 at Lewes, Sussex, and, at the age of sixteen, became Junior Assistant in the map room of the Royal Geographical Society, thus entering on a lifetime of service to travellers and all students of scientific geography. By his own determined efforts he soon acquired a mastery of his subjects and as a result of this achievement he was appointed to the position of map curator in 1900. In 1901 he became instructor in practical astronomy and surveying, and in 1904 superintendent of the map drawing department, which post he held until his retirement in 1933.

His kindly, modest nature won for him the confidence and affection of his students, and practically all the eminent travellers of his day, from Stanley onwards, consulted him and travellers to all parts of the world are to be found among his students. In the course of his work Reeves not only instructed and trained men who wished to explore, but also examined the records and observations of the returning travellers and verified their discoveries. He also found much pleasure in welcoming students at his Surrey observatory and thus developing their interest in the study of the heavens.

His written work includes the re-editing of *Hints to Travellers, Maps and Mapmaking* (1910), *Trigonometry Plane and Spherical*, and *The Recollections of a Geographer* (1935).

The honours awarded him were well earned not only for his own scientific work but

also for the inspiration he infused in others. In 1922 he was given the Cullum Gold Medal of the American Geographical Society and in 1928 the Victoria Gold Medal of the Royal Geographical Society for research.

In 1888 Reeves married Grace Eden Harley and died at his home in Reigate on 1945 October 17, survived by his widow, son and daughter.

He was elected a Fellow of the Society on 1896 April 10.

FRANK ROBBINS was born at Holloway, London, on 1860 November 23. He attended the City of London School. He entered the service of the Corporation of the City of London, becoming, in course of time, one of the four gas examiners for the City. This position he retained until he was some years beyond the usual age of retirement. He lived all his life in London, and only left, in 1941, when compelled by ill-health. He died at Chard, Somerset, on 1945 May 4, at the age of eighty-four.

Early in life he became interested in analytical chemistry and astronomy. At first his astronomical interest seems to have been of the popular kind, but curiosity as to the way in which sailors find their way at sea led him to begin the serious study of mathematics. In earlier years he appears to have confined himself to those branches which have a direct bearing on astronomy, but he gradually extended his study to other branches, giving special attention to those methods that lead most readily to numerical results. About 1885 he sent to the *English Mechanic* a question concerning a passage in Herschel's *Outlines of Astronomy*. To this, R. T. A. Innes replied and offered help. There resulted a warm friendship and a regular correspondence, usually at weekly intervals, which lasted until Innes died in 1933. Robbins regarded his association with Innes as the outstanding influence of his life.

Robbins was elected a Fellow of the Society in 1890. He was most regular in attendance at the meetings, and acted as Auditor in 1922–26. The great advantages of membership were a frequent theme, and he lost no opportunity of introducing suitable persons to the Society. He joined the British Astronomical Association in 1926, and served for some years as Treasurer (1927–31) and then as Vice-President (1931–32). In 1930 he was co-opted a member of the Mathematical Tables Committee of the British Association: he rendered much help, especially in reading the proofs of the series of volumes which were published between 1931 and the outbreak of war in 1939. He attended the meetings of the International Astronomical Union in 1925, 1928 and 1935.

On retiring, at the age of seventy, from his work in the City, he took, without the break of even a single day, an honorary position as observer at the University of London Observatory, Mill Hill, and thus realized, in some measure, his early ambition of becoming a professional astronomer. In order that he might be available at any hour of the night he took a lodging in a nearby house, and used to assert that he had never missed making an observation by failing to reach the Observatory in good time. Among his various duties was the demonstration of the instruments to members of the public. In this he showed a high degree of toleration for the inanities of some of the visitors, though it may be doubted if he ever succeeded in suffering fools gladly. Occultations were his chief study while at the Observatory; an account of which is contained in the *Monthly Notices*, **98**, 428, 1938. When he had to give up his work at the Observatory he did so with very great regret.

The literary output of Robbins consisted of about twenty papers of a total length of some 150 pages. These appeared for the most part in the *Monthly Notices* and in the *Journal of the British Astronomical Association*. Among them are reviews, biographical articles—mainly of the gold medallists of the R.A.S.—and papers in which astronomical difficulties are discussed and elucidated. His first paper, on the "Ephemeris of Eros" (*M.N.*, **60**, 612, 1900), was a work of great labour, and typical of his computational zeal and ability. A table entitled "Factorials and Allied Products with their Logarithms" appeared in the *Transactions of the Royal Society of Edinburgh*, 1917. A

number of his computations were embodied as appendices to papers of Innes. In all these papers there is evidence of wide and careful reading and of painstaking thought. He was not a facile writer, and each paper involved an amount of effort of which its length is little indication.

Robbins regarded himself primarily as a student. As a computer he achieved a high degree of skill; as a mathematician, his attainment was such as can rarely have been excelled by one whose serious reading did not begin till he was over twenty-five. In a number of other subjects his knowledge was exceptional. He was throughout eager to learn, and always prepared to revise his opinions on sufficient evidence. Though his chief interest was astronomy, he was constantly contemplating the riddle of life, its origin, purpose and destiny; and because he thought deeply, he was apt to be impatient of the shallow answers that are so often given to profound questions. His attitude to life is perhaps expressed best by the collection of quotations brought together in his short paper "Hindrances of a Student" (*J.B.A.A.*, **38**, 180, 1928), and particularly by one of them: "Ever to seek and never to find—the quest retaining its attractiveness."

A. J. THOMPSON.

ARTHUR LAIDLAW SELBY was born on 1861 July 2, and died on 1942 July 22. He graduated at Oxford University (Queen's College), and became Demonstrator in Physics at the Clarendon Laboratory (1884) and a Fellow of Merton College (1886). In 1890 he came to Cardiff as Assistant Professor of Physics in the University College, joining the brilliant team got together by Viriamu Jones, the first Principal. In 1897 Selby succeeded to the Chair, which he held until his retirement in 1926. Shortly before this he married Miss Dorothy Beck.

As Professor Emeritus he continued to take the keenest interest in the college to which he had given devoted service for so many years. His critical judgment, his sure instinct for policies which he considered (and which proved) "sound" and his unwavering sense of justice put him among the half-dozen or so men who shaped the destinies of the young and growing University of Wales, and in particular of his own college.

He became a Fellow of the Royal Astronomical Society in 1891. While there is no evidence that he took an active part in astronomical work, he was deeply interested in the development of the science, especially on its astrophysical side, and he greatly admired the work at South Kensington of Lockyer and Alfred Fowler. His wide outlook on affairs was that of the historian, and he was always alive to the part astronomers had played in the shaping of Western thought. In his class-work he was fond of illustrations drawn from astronomy and meteorology, and the astronomical aspects of relativity.

He was essentially a mathematical rather than an experimental physicist, but took the keenest interest in the researches of his staff, who owed much to his shrewd and friendly criticism. He was a man for whom colleagues not in the closest touch with him felt respect rather than affection, but those who knew him best knew too that he was a loyal and generous friend, one who never harboured a mean thought, never acted for his personal advantage, and, a rare gift, was capable of reversing his attitude in a situation when convinced that justice lay the other way. The writer will always remember an instance when a matter of great import to the junior staff was up for adjudication. Selby and other influential members of Senate had expressed the view that the claims were unjustified and their presentation unscrupulous, and matters were tense. But when it was explained to him what lay behind the difficulty, he ceased to oppose, made himself the spokesman for the claims and brought them to fruition.

His services to Cardiff and to many generations of its students were commemorated by the establishment of a "Selby Lecture", delivered by distinguished physicists and astronomers, including the Astronomer Royal. At five of these lectures Selby was present—one could wish that such acknowledgments of indebtedness and gratitude were more often made thus during the lifetimes of those they honour.

J. H. SHAXBY.

WILLIAM NAPIER SHAW, who died at his home in London on 1945 March 23, was born in Birmingham on 1854 March 4, his father being a manufacturing goldsmith and jeweller. He was educated at King Edward's School, Birmingham, and Emmanuel College, Cambridge. At Cambridge he read mathematics, and was sixteenth wrangler in the tripos of 1876. In the natural sciences tripos examination held later in the same year he obtained a First Class, with distinction in Physics. His College elected him to a Fellowship in the following year, and Shaw made Cambridge his home for the next twenty-two years.

In 1885 he married Sarah Harland, lecturer in mathematics at Newnham College, daughter of Dr. Thomas Harland of Salford. She died in 1923.

Shaw and R. T. Glazebrook were appointed by Lord Rayleigh as joint demonstrators in the Cavendish Laboratory, and their association led to the publication in 1885 of their *Textbook of Experimental Physics*, known to many generations of students as a standard textbook. In 1887 Shaw was appointed University Lecturer in Experimental Physics, and in 1898 was appointed Assistant Director of the Cavendish Laboratory, a post which he held for a short time only.

Shaw's first contributions to meteorology were a report on the performance of the evaporimeters then in use, and a general discussion of the problem of hygrometry. This discussion was published in the *Philosophical Transactions of the Royal Society* in 1888. Shaw was also deeply interested in the problems of heating and ventilation of buildings, and was consulted with regard to heating and ventilation of the House of Commons, of the meeting-room of the Royal Society, of the examination-rooms of the University of Cambridge, of the new buildings of the University of Wales, at Cardiff, and of many other buildings of all kinds. Some of the physical principles involved in these problems are given in his little book on *Air Currents and the Laws of Ventilation*, published in 1907.

About the end of 1899 Shaw left Cambridge to come to London, where he succeeded R. S. Scott as Secretary of the Meteorological Council, thus becoming head of the Meteorological Office. In 1905 his post became that of Director of the Meteorological Office, while the Council was replaced by a committee directly responsible to the Treasury. One of Shaw's early tasks was the design of the premises in Exhibition Road, South Kensington, to which the Meteorological Office was removed in 1910; long before the end of the war, in 1918, this building had become quite inadequate to house the activities of the Office. Under Shaw's direction the scope of the work of the Office had grown with great rapidity; the networks of observing stations previously maintained by the Registrar-General, the Royal Meteorological Society and the Scottish Meteorological Society had been taken over by the Office and the observatories at Kew and Eskdalemuir had also been transferred to its care.

At an early stage of his career in the Meteorological Office, Shaw became active on the International Meteorological Committee, of which he became President in 1906, retaining this position for three years after his retirement from official meteorology in 1920. The respect and affection of the leading meteorologists of the world towards Shaw were nowhere more clearly shown than at international meetings, where it could be said without exaggeration that where Shaw sat, there was the head of the table.

Shaw's scientific contributions to meteorology were many. His book *Forecasting Weather*, which may be described as an essay in writing the physics of the atmosphere, appeared in 1911, and has gone through three editions. This, together with *The Life-History of Surface Air Currents*, shows Shaw's attitude towards his subject more clearly than anything else he wrote. For it is no great (if any) exaggeration to say that when Shaw came to meteorology he found it an exercise in arithmetic, and that he made it a branch of physics. *The Life-History of Surface Air Currents* goes a long way towards establishing what later became known as the Polar Front Theory of Cyclones, and many meteorologists must have wondered, as did the present writer, why Shaw did not carry the work described in this memoir to its logical conclusion. It appears that soon after

the publication of this memoir Shaw spent a week-end with W. H. Dines, who had then established the high correlation between the pressure at 9 kilometres and the mean temperature from 0 to 9 kilometres. Shaw became convinced that the secret of the genesis of the depression was to be found at 9 kilometres, and so far as the present writer is aware he devoted no further study to the life-history of surface air currents. He thus missed the chance to establish the polar front theory, to which he had made such a near approach. The use of the millibar as the unit of pressure, first advocated by V. Bjerknes, was adopted largely through Shaw's efforts, and was first used in the British *Daily Weather Report* on 1914 May 1. In the investigation of the upper air by means of kites and balloons Shaw himself worked in association with the late W. H. Dines, and inspired others, such as C. J. P. Cave, to work in the same field. The war of 1914–18 soon showed the importance and usefulness of the upper-air observations, and the war period was one of considerable activity for the Meteorological Office. The administrative work of the Office was taken over by Sir Henry Lyons in 1918, Shaw being appointed Scientific Adviser on Meteorology to H.M. Government. It was at this stage of his career that he began his long-deferred and self-imposed task of writing a comprehensive textbook of meteorology, which finally took the form of the *Manual of Meteorology*, in four large volumes, of which the fourth appeared in 1931.

When Shaw left the Meteorological Office in 1920 he was appointed to a Professorship in Meteorology (part-time) at the Imperial College of Science and Technology, South Kensington, and held this appointment until he was succeeded by Sir Gilbert Walker in 1924.

In the *Quarterly Journal of the Royal Meteorological Society*, 1934 April, will be found an article by Shaw entitled "The March of Meteorology", in which he gives some reminiscences of his long career. It is full of interesting matter, and well repays the time spent in reading it.

During the whole of his long career Shaw was an active member of many scientific associations. He was President of Section A of the British Association in 1908, and of Section L in 1919. He was able, with the assistance of the late Sir Norman Lockyer, to induce the International Meteorological Committee to form a "Réseau Mondial Committee", to have as its duty the collection of adequate data to provide monthly summaries for each square of 10° of latitude and longitude. The Atmospheric Pollution Committee was brought into being through the joint efforts of Shaw and Dr. J. S. Owens, and some of the results of observations, made mostly by Owens, were described in a fascinating book entitled *The Smoke Problem of Great Cities*, by Shaw and Owens. The Advisory Committee on Aeronautics was brought into being by Shaw and R. T. Glazebrook, in continuation of a collaboration which lasted until Glazebrook's death. They worked together at the Imperial College, where the Chair of Meteorology was attached to the Department of Aeronautics, of which Glazebrook was head. On the foundation of the International Union of Geodesy and Geophysics, Shaw became President of its Meteorological Section, and acted in that capacity at the meetings in Rome (1921), Madrid (1924), Prague (1927) and Stockholm (1930). These activities were in accord with the many-sided interests of his life while a tutor at Cambridge, where he was the prime mover in inducing a group of colleges to hold combined scholarship examinations instead of each holding its own examination. It was as a result of Shaw's efforts, too, that there came into being in 1899 the Cambridge Appointments Association, which was later to become an official University organisation, with the title of Cambridge University Appointments Board. Shaw was President of the Royal Meteorological Society during the two years 1919 and 1920, and was Vice-President of the Physical Society in 1917–18.

Shaw's work was recognised by the award of many honours. He was knighted in 1915. He became a Fellow of the Royal Society in 1891, and was awarded a Royal Medal in 1923. He was awarded the Symons Medal by the Royal Meteorological Society in 1910,

and the Buys Ballot Medal of the Dutch Royal Academy in 1923. Honorary degrees were conferred upon him by the Universities of Aberdeen, Athens, Dublin, Edinburgh, Harvard and Manchester, and he was a foreign member of the Academies of Boston, Oslo, Rome and Stockholm, and of many other foreign societies.

Shaw left a very distinctive mark on meteorology. He approached the subject from the physical point of view, and by his insistence on this did more to set his subject on the road to progress than anyone else of his own generation. He was at all times ready to listen to views contrary to his own, and though often tenacious of his own opinion, would listen to the opposite opinion with sympathy, and was open to conviction should the opponent produce sound arguments. He instituted the Monday evening discussions at the Meteorological Office in Exhibition Road, and it was there that many visiting scientists saw Shaw at his best. He will be remembered with affection by many who worked in close association with him during a scientific career which extended over more than threescore years. The devotion of those who worked in closest contact with him will be an abiding memory with all his friends.

He was elected a Fellow of the Royal Astronomical Society on 1919 April 11.

D. BRUNT.

ALAN JAMES SKINNER was born at 64 Cambridge Road, Anerley, London, S.E. 20, and died of typhoid fever at Dehra Dun, United Provinces, India, on 1945 May 3, when on Active Service.

He was educated at Whitgift School, Croydon, going on to Clare College, Cambridge, with an open Scholarship. He took his degree in 1940.

He was an able mathematician, and the outbreak of war found him devoting all his attention to astrophysics.

He joined the Army Operational Research Group in 1940, where he applied scientific methods to anti-aircraft and infantry problems. In 1944 he joined a scientific research section in India with the rank of Staff Captain.

He was elected a Fellow in 1941 May 9.

FREDERICK SLOCUM was born at Fairhaven, Massachusetts, on 1873 February 6. His father had been master of a whaling ship, and one of his brothers was a sea-captain. In his youth he spent a great part of his free time on the water, and earned as a fisherman much of the money he spent as a student. He was a graduate of Brown University, Providence, Rhode Island, in the class of 1895, and a member of its faculty for the fourteen years immediately following his graduation. He held four degrees from Brown University, A.B., A.M., Ph.D. and honorary Sc.D. For the first five years of his teaching at Brown University he was Instructor in Mathematics, but in 1900 he became Assistant Professor of Astronomy under Winslow Upton, Director of the Ladd Observatory, a notable teacher who greatly influenced his pupil and colleague.

The academic year 1908–9 was spent by Slocum at the Royal Astrophysical Observatory at Potsdam, Germany, a centre of the rising science of astrophysics, where Hartmann, Kempf, Müller, Scheiner and Wilsing were developing new methods in spectroscopy and photometry. On his return to America he became a member of the staff of the Yerkes Observatory of the University of Chicago, where he remained five years. Here he carried on research with the 40-inch refractor, using the Rumford spectroheliograph by day for photography of the solar disk, chromosphere and prominences, and by night taking plates for stellar parallax and proper motion with the double-slide plateholder. The results of these observations appeared in a series of papers in the *Astrophysical Journal*, the *Monthly Notices* and other periodicals. In 1914 he resigned to become Professor of Astronomy at Wesleyan University in Middletown, Connecticut, and Director of the Van Vleck Observatory.

Slocum's first duty in Middletown was to plan and build the observatory. It was intended both for instruction in astronomy and for investigation, and he considered that a single 18½-inch visual refractor would serve as an exceptional teaching instrument and also be adequate to furnish material for a worth-while research programme. Believing that a small institution should concentrate upon a single programme, and feeling strongly the value of co-operative effort, Slocum chose, as the programme of investigation at the new observatory, the determination of stellar parallaxes. This was an enterprise in which several American and European observatories were already engaged, and in which he had himself had much experience at Yerkes.

Though the observatory was completed before the United States entered the first world war, the glass disks for the lens of the telescope, ordered from Germany, could not be delivered. Also, from 1917 to 1920 Slocum gave up his astronomical activities to give instruction in navigation to merchant mariners, for the United States Shipping Board, and to students at Brown University. But soon after his return to Wesleyan it was possible to finish the telescope, giving it a 20-inch aperture instead of the original 18½, and to begin the planned programme, which continued without interruption under his direction until the end of 1942. The staff of the observatory was increased by one and then two men of faculty rank, with additional full-time and part-time assistants in later years. A volume containing parallax determinations of 130 stars was published in 1938, and a great many more await publication. In addition to this research work, from three- to five-year courses in astronomy were usually given to students. During this period Slocum took only one year's leave of absence, spending it at the Mount Wilson Observatory. He observed two total solar eclipses (1925 and 1932) in New England, and journeyed to Norway for the eclipse of 1927, where clouds prevented observations.

In the winter of 1942–43 work at the Van Vleck Observatory was cut short by the establishment of a Navy Flight Preparatory School at Wesleyan. The two junior members of the staff transferred their full time to the school, and Dr. Slocum took over all the instruction in astronomy and gave additional classes in navigation for the next eighteen months. In the summer of 1944 his health began to fail rapidly, and after only a few months of helplessness he died at Middletown on 1944 December 4.

Dr. Slocum was a very skilful and resourceful observer, a keen interpreter and judge of the results of observation, an exceptionally fine teacher, and a man of great integrity and balanced judgment. His personal influence went far beyond his circle of official responsibility at all times, and he had a host of warm friends, many of whom owed much to his counsel, both in America and throughout the world. He was a member of the Société Astronomique de France, of the Astronomische Gesellschaft, and of the Commission on Stellar Parallaxes of the International Astronomical Union. He served as Vice-President and Chairman of Section D of the American Association for the Advancement of Science, Vice-President of the American Astronomical Society and member of the National Research Council.

During his instructorship at Brown University Dr. Slocum married Carrie Tripp of New Bedford, Massachusetts, who was his constant companion until her death in 1942.

He was elected a Fellow of the Society on 1911 November 10.

B. W. SITTERLY.

EDWARD BRUCE HERSCHEL WADE was born on 1872 November 8 in Pekin, where his father, Sir Thomas Wade, was then living as Minister Plenipotentiary in China. His mother was a daughter of Sir John Herschel.

Wade was educated at Winchester and proceeded to Trinity College, Cambridge, where he took a First in Natural Science. He then was offered a post in the Egyptian Survey Department under Sir Henry Lyons (then Captain Lyons, R.E.). While in the Egyptian Service he took charge of the old Observatory at Abbasia near Cairo, which had an old Mertz refractor of about 7 inches aperture. Then came the building of the Helwan Observatory in 1904 and Wade for a time was transferred to the Geodetic Survey. In 1905 he led the Egyptian-Turkish Boundary Commission with the late B. F. E. Keeling. He communicated several papers to the Royal Astronomical Society on the determination of desert positions, and especially one on a two-angled cœlostat for comparison of the Moon's position with a field of stars some angular distance away. In 1921 he wrote a paper on "A method of determining longitudes by observations of the Moon", and in 1923 "A method of determining small differences in latitude". Both these and several others appeared in the publications of the Egyptian Physical Department.

He retired on pension in 1925 and then went to live at Geneva, where he remained until the war. He was much interested in music, and one of the recollections the writer has of him is of a tent near the Observatory at Helwan, which contained an upright piano with a wooden frame, split by the dry hot climate, on which he played and composed "Songs of the Desert", a copy of which the writer still has.

Wade never married, and in later life he devoted himself to music almost entirely, but unfortunately he developed deafness in Egypt and ultimately became stone deaf. He died in London on 1945 September 28.

J. H. REYNOLDS.

ERNEST HENRY CHARLES WUNDERLICH was born in London on 1859 May 16, and died on 1945 April 11 in Sydney, Australia. He was educated in Germany and Switzerland, and at the age of nineteen he entered business as a clerk in a London firm. However, this work soon proved too monotonous, and after working for various firms in England and South Africa he went to Australia in 1885.

Here Wunderlich enjoyed a long and successful business career, besides living a very full life, travelling, composing songs and music for the piano, and taking a leading part in the musical society of Sydney. He had a strong interest in astronomy, and possessed a small transit instrument and a $4\frac{1}{2}$-inch telescope in his observatory at Port Hacking; he used to observe sunspots and planetary phenomena, though he did not do any systematic work in these fields. Although his equipment was comparatively small it was all of first-class quality and kept in very good working order. In 1924 he established a trust by which his equipment was made available for use by the New South Wales Branch of the British Astronomical Association, and since that time it has been used by a number of observers, chiefly in the study of variable stars. He was a member of the Board of Visitors of Sydney Observatory.

Wunderlich married Fanny, daughter of Rudolph Hoesch, in 1885.

He became a Fellow of the Society on 1922 November 10.

JAMES YOUNG, who died of leukæmia at the age of forty-seven in 1945 May, was an unusual instance of a professional physicist who nevertheless became more devoted to astronomy than to astrophysics. His lectures on spherical and dynamical astronomy, and his observatory classes, had for twenty years influenced Birmingham University students to a far greater extent than was known to most Fellows who merely saw his annual reports of lunar occultations in the *Monthly Notices*. As a boy in Scotland he had been drawn to observational astronomy, and in his student days at the Royal College of Science, London, he was much encouraged by Alfred Fowler's courses; but to the end of

his life he really preferred the precision of celestial geometry rather than the laboratory spectroscopy, which Fowler's researches and his own position as physics lecturer might have disposed him to follow. The writer used to share Young's university work, supplementing his friend's course by introducing topics of stellar and solar radiation and ionization, more commonly classified as astrophysical; but everyone was aware that the clarity and brilliance of Young's expositions in spherical astronomy and planetary or lunar positions and orbits had a power unequalled in the writings or discussions of anyone else, and his selection of topics unusual to a physics laboratory was abundantly justified. He was, however, a somewhat solitary and uncommunicative colleague though a very lovable and loyal friend, and he never evinced the slightest desire to publish his exquisite teachings for competition with standard texts: he seemed content with the intrinsic delight in the work without notoriety or even widespread companionship. So Young organised the University Observatory, with its 7-inch Cooke photovisual, into a service of precise and painstaking records, especially of lunar phenomena, unknown to most scientific circles around; it was a work dictated by a private æsthetic delight completely independent of any motive of gain or fame, but he would welcome student help if accompanied by willingness to face his own standards of intellectual rigour. His secret was a very remarkable geometrical imagination and a passion for quantitative austerity: it was characteristic that, as a physicist, Young's most original lectures were on crystal structure, Lorentz relativity, optical design and other subjects demanding high geometrical skill, and his best researches also concerned crystals, metallic or organic, and a recent preoccupation with paraboloidal mirror projection. But he had geological interests, and combined them with his lunar observational work in a monumental series of photographic measurements on the Moon's craters: his statistical analyses of their distribution in size, ellipticity, etc. afforded clues to possible origins, volcanic or meteoric, and some of this work was published by the B.A.A. It is hoped that when all his manuscripts have been sorted there may be more to come.

He was elected a Fellow on 1924 January 11. MARTIN JOHNSON.

MEADE LAFAYETTE ZIMMER was born on a farm in 1880 not far from Albany, the capital of New York State, U.S.A. His education in the little country schoolhouse did not take him very far along the road to learning, but he studied alone (while teaching), and passed the examinations which admitted him to college. He had always been very interested in all branches of science, especially astronomy, so he was quick to take advantage of the opportunity to become a member of the staff of Dudley Observatory, in Albany, when he received his diploma from Union University in 1906. He spent two years there, preparing himself to take part in an expedition to San Luis, Argentina; before leaving the country he received his M.A. degree from Union University.

He spent over three years in San Luis, making observations with the meridian circle and helping to reduce them, and later did some work on photometry. When the position of first astronomer at the National Observatory of Argentina, situated in Cordoba, fell vacant, he applied for it and took charge of the department of meridian circle astronomy there for thirty years. He had entire charge of the clocks as well, and greatly improved conditions by designing a room thirty feet below the surface where the clocks would not be affected by changes of temperature.

Zimmer published various articles in English and Spanish magazines, and the reductions of his research work, "Catalogo Fundamental" (1929) and "Catalogo Fundamental General" (1941), are to be found in Volumes 35 and 37 of *Resultados del Observatorio Nacional Argentino.*

He found his relaxation in tennis and in working on models of inventions; he had several U.S. patents to his credit. He also did much to improve the mechanism of apparatus which was used in the observatory. He always continued to study, and received his Ph.D. in Astronomy in 1926 from the University of Michigan, and in 1931

the Union University gave him the degree of D.Sc. Once his work in Cordoba was finished he returned to the States, and his arrival there coincided with the entry of the country into the war. He was, therefore, able to offer his services to the Government, and was given research work in a completely different line of science. Unfortunately his health was not too good, so he was not able to put in such long hours of work as he had done formerly. In 1945 the doctors felt that an operation might improve his condition and gave him every hope of a complete recovery, but his death came a week after the operation, on February 5. His wife, two sons and a daughter survive him.

He was elected a Fellow of the Society on 1922 December 8.

AGNES S. ZIMMER.

FRANCISCO MIRANDA DA COSTA LÔBO was born at Vinhais, Portugal, on 1864 February 18. While still a young man he became Professor at the University of Coimbra and Director of the Astronomical Observatory of the University. There he originated an astrophysical department with special regard to solar work. He installed a spectroheliograph modelled closely on the one at Meudon, working in close touch with Professor Deslandres and M. d'Azambuja. In the design of the Costa Lôbo stellar spectrograph he acknowledged the help of Sir David Gill. The instrument is an objective prism spectrograph equatorially mounted, and convertible into an ordinary equatorial by removing the prism and the system of reflectors in the finder, which was used to produce a deviation in the beam corresponding to that of the prism.

Da Costa Lôbo, before his retirement from the Directorship of the observatory in 1932, inaugurated the *Anais do Observatorio Astronomico da Universidade de Coimbra*, which give reproductions of the daily spectroheliograms obtained at Coimbra; the diameter of the solar image for these is 88 mm. In special cases sunspot drawings from an image 40 cm. in diameter are added. Selected meteorological and magnetic elements are also given. In addition to his solar work da Costa Lôbo took charge, as Honorary Director, of Coimbra Observatory's contribution to the international scheme for the determination of longitude by wireless in 1933. He served on the Corresponding Commission of the I.A.U., as well as on four of the Commissions dealing with the Sun, namely those on sunspots, solar character figures, chromospheric phenomena and eclipses. He organised two expeditions for the eclipses of 1900 and 1912. The outbreak of war prevented his leading a party to Russia in 1914. He was a familiar figure at I.A.U. meetings, attending all meetings from 1923 to 1935.

In addition to being President of the National Committees of Astronomy and of Geodesy and Geophysics, he was President of the National Council of Research and President and Director of the Science Faculty of the Institute of Coimbra. He organized the meeting in 1925 at Coimbra of the Portuguese Association for the Advancement of Science, of which he was President, and he also organized the Congress of the International Union of Geodesy and Geophysics at Lisbon in 1932. He had a wide range of outside interests, including history, economics, education and agriculture.

Da Costa Lôbo was always a strong supporter of the long-established alliance between Portugal and Great Britain, and a room in the observatory was dedicated to the memory of Sir Isaac Newton on the occasion of the bicentenary of his death at a ceremony attended by the British Ambassador to Portugal and by the Astronomer Royal, Sir Frank Dyson.

Various foreign honours came to da Costa Lôbo, including the Grand Cross of Alfonso XII; he was Commander of the Legion of Honour, Commander of the Order of Leopold of Belgium, Count of the Holy Roman Empire, member of the Royal Academies of Science and of History of Madrid, foreign member of the Pontifical Academy of Science and Correspondent of the Bureau des Longitudes of Paris. He received the Janssen Prize of the Académie des Sciences of Paris.

He was elected an Associate of the Society in 1934.

He died at Coimbra, 1945 April 29.

F. J. M. STRATTON.

MARIE PAUL AUGUSTE CHARLES FABRY was born in Marseilles on 1867 June 11. He came of a family with scientific interests: his grandfather had been a pupil of Ampère at the École Polytechnique; two of his elder brothers were Correspondents of the Académie des Sciences, Eugène in Geometry, Louis in Astronomy: with them he spent nights in his boyhood observing eclipses of the satellites of Jupiter. He himself was later to become a member of the Academy in the section of General Physics.

After a brilliant career at the École Polytechnique he secured his *agrégation* in Physics in 1889 and his doctorate in Physical Sciences in 1892 with a thesis on "Théorie de la visibilité et de l'orientation des franges d'interférence"—a clear indication of the line of study that he was to follow up so brilliantly. After teaching physics in several Lycées he returned to Marseilles in 1894 as Chief Lecturer in Physics in the University under Macé de Lépinay as Professor. Here he found Alfred Perot already in charge of the teaching of industrial physics and a most fruitful partnership in research and publication of results followed, which lasted until Perot was called to a post in Paris: Henri Buisson who succeeded him became in his turn the faithful friend and disciple of Fabry and collaborated with him in his optical researches. Fabry's obituary notice of Buisson in *Nature* was one of the very few communications of French savants to reach England during the years of the recent war.

In 1904 Fabry succeeded to the Chair of Physics at Marseilles University and continued there researching in optics and teaching industrial electricity. His weekly lectures on Wednesday evenings attracted overflowing crowds of students, engineers and artisans—a triumphant testimony to his lucidity, simplicity and humour. The war of 1914–1918 took him at last away from his beloved Marseilles, first with mobile radiographic units, then as technical adviser to the Artillery in the National Office of Research and Inventions under Paul Painlevé, then as head of a scientific mission to the United States; his reception there opened the eyes of his fellow-countrymen to the position he had gained in the international world of science, and in 1920 he was the inevitable choice as Director of the Optical Institute founded as the result of the efforts of the Duc de Gramont and Monsieur Chrétien. This Institute was the final ruling passion of his life, and its importance for the progress of industrial optics in France can be measured by astronomers by such developments as we have known in astronomical instruments at the hands of a younger school of brilliant French astrophysicists. Fabry was made Professor at the Sorbonne in 1921, where he and Professor Cotton shared the teaching of general physics.

At his seventieth birthday in 1937 arrangements were made for the publication of a selection of his scientific memoirs. The mere list of his papers on Interferometry, Spectroscopy, Photometry, Metrology, Electricity, Geophysics and Astrophysics takes up thirteen pages. The safest guide to those of most interest to astronomy in his early day is the selection made by the editors of the *Astrophysical Journal* in the days when it was still possible for translations of foreign papers to be published in its columns. The first so chosen was "On a New Form of Interferometer", a description of the now well-known Fabry-Perot Interferometer (*Ap. J.*, **13**, 265, 1901). Then in quick succession came a series of papers on absolute wave-lengths in the spectrum of iron and cadmium and a study of the establishment of a new system of standard wave-lengths badly needed in solar and stellar spectroscopy as well as in the laboratory. Perot, Benoit or Buisson collaborated in many of these papers but the sure hand of Fabry was present throughout.

The work on standard wave-lengths was followed by interferometric studies of very small displacements of spectral lines; in particular the differences between the iron arc and the solar spectrum were examined and the displacements to the red of the lines of the solar spectrum at the limb relative to their wave-lengths at the centre of the Sun's disk. Later, in a couple of well-known papers (*Ap. J.*, **33**, 406, 1911 and **40**, 241, 1914) he applied his objective interferometer to the Orion nebula to study the wave-lengths

of the then unidentified nebular lines, the relative line-of-sight velocities of different parts of the nebula and the temperature of the luminous gas.

His spectrophotometric work included an examination of the ultra-violet spectrum of the Sun and the distribution of the energy of the solar spectrum for the range $\lambda$ 3150 to $\lambda$ 2900 A. (*Ap. J.*, 54, 197, 1921). His study of the ozone in the atmosphere, made in connection with this work, provided a link with meteorology and led to his presidency of the Société Météorologique de France. His report on "Astronomical Photometry and that of the Physicists" (*Annuaire du Bureau des Longitudes*, 1933) is a most illuminating statement of the problems facing the two classes of workers and of the underlying principles and precautions which they have to adopt. His own photometric work was mainly in the laboratory, but he also examined the brightness of the night sky and of the corona and also the absolute magnitude of the Sun relative to the stellar magnitude scale. One more line of work in astronomy is revealed in his George Darwin Lecture to the Society on "Interstellar Space" in 1938, an echo of an early paper, "Remarks on the Temperature of Space" (*Ap. J.*, 45, 269, 1917).

No record of his life would be complete without reference to the part that he played in the world of international science. As long ago as 1904 he was working on standard wave-lengths for the International Union for Solar Research and the Bureau International des Poids et Mesures, and from 1905 onwards he served on the Committee of the International Union for Solar Research on Standard Wave-Lengths. He was a member from the start of the Committees of the International Astronomical Union on Standard Wave-Lengths, and Tables of Solar Spectra, Spectrophotometry and Astronomical Instruments. Of the last-named Committee he was President from 1928 to 1938 and *Président d'Honneur* at the time of his death. He also served on the Committees on Nebulæ and Stellar Photometry. He was twice a Vice-President of the Union: 1932–35 and 1938–45. He was also a member of the Committee on Solar and Terrestrial Relationships of the International Council of Scientific Unions: he became President of the Council in 1937, resigning for reasons of health in July 1945. He attended as a representative of France, a well-known and ever-welcome figure, international gatherings at Oxford, 1905, Meudon, 1907, Mount Wilson, 1910, Cambridge, 1925, Leiden, 1928, Paris, 1935, and London, 1937.

None who have had the privilege of working with him can have failed to recognise his lucidity of expression, his breadth of outlook, his wisdom, his sense of humour and his humanity. His deep love of his country must have brought him much sorrow in the last years of his life, but he happily survived to see a liberated France taking the first steps on the road to recovery.

His honours included the Rumford Medal of the Royal Society in 1918, the Draper Medal of the National Academy of Sciences in 1919, the Franklin Medal of the Franklin Institute in 1921. He was elected as a member of the Royal Institution in 1920, of the Franklin Institute in 1921 and Foreign Member of the Royal Society in 1931. He was made an Associate of the Royal Astronomical Society on 1915 June 11.

He died in Paris on 1945 December 11.

F. J. M. STRATTON.

# PROCEEDINGS OF OBSERVATORIES

*Royal Observatory, Greenwich*
(*Director, Sir Harold Spencer Jones, F.R.S., Astronomer Royal*)

The restricted programme of observations with the Airy transit instrument has been continued. Observations of the Moon were resumed in December. 88 observations of the Sun, 3 of the Moon, 36 of Venus and 16 of other planets were obtained, together with 786 transit and 653 zenith distance observations of stars.

The reversible transit circle, which had been partially dismantled in 1940 September, was brought into operation after the termination of the war in Europe. Further investigations of the errors of figure of the pivots are in progress.

Progress has been made with the preparation of the *First Greenwich Catalogue of Stars for 1950*, based on observations in the years 1931 to 1940. Part I will contain the positions of fundamental stars and of stars used in the programme of observations with the Cookson Zenith Telescope. Part II will contain the positions of stars in the zone $+0°$ to $+24°$ declination. The proper motions of some 2100 stars not contained in the Albany *General Catalogue* are being derived.

The construction by Sir Howard Grubb, Parsons & Co. of the photographic zenith tube has been commenced. Further consideration has been given to the detailed design of the various parts of the instrument and of the ancillary equipment. Laboratory tests have been carried out on methods of obtaining accurately timed indications of the position of the plate carriage, and one of the methods devised may have applications to other astronomical or measuring instruments. The mounting and movement of the plate carriage has been redesigned in a form which should ensure adequate precision, and a simple mechanism has been designed to impart uniform motion to the carriage without the use of a screw. Tests on phonic motor drives have been carried out both by the Observatory and by Sir Howard Grubb, Parsons & Co.

Construction of the experimental model of the horizontal transit instrument is still in progress and various detailed points of design have been investigated. Tests have been carried out in the laboratory, and further experiments are planned.

As the resumption of the stellar parallax programme with the 26-inch refractor is not possible at present, on account of the damaged condition of the dome, arrangements have been made with H.M. Astronomer for the wide-angle lens camera plates in the zone of declination $-56°$ to $-60°$, taken at the Cape Observatory, to be measured and reduced at Greenwich.

The Sun was photographed at Greenwich on 261 days. From reports received from the Cape and Kodaikanal Observatories, the number of unrepresented days in the combined series of photographs should not exceed four during 1945.

The transmission of the Cape and Kodaikanal negatives held up by the war has now been resumed. Cape original plates have been received up to 1942 January and duplicate plates up to 1941 April. Kodaikanal plates required to fill the gaps in the Greenwich-Cape series have been received for 1939 and 1940. Measurements of the combined series have been made to 1940 October 31 (except for six Kodaikanal plates), and those for the Greenwich plates alone extended to 1945 June 12. Positions and areas of sunspots have been computed from the combined series to 1940 April 30, and from the Greenwich plates alone to 1945 May 31.

The Sun's disk was observed in $H\alpha$ with the spectrohelioscope on 161 days; on 28 of these, observations were possible for only 15 minutes or less. 182 measures for radial motions were made on normal patches of bright flocculi (these measures also giving

effective line-widths); 299 measures on dark flocculi and 32 on prominences at the Sun's limb. During the year, 23 sets of photometer measures were made on normal bright flocculi and one set on each of 11 solar flares, one of which (October 15) just exceeded the intensity of the continuous spectrum 15 A. from the centre of *Hα*.

An investigation into occurrence at Greenwich of sudden commencements of magnetic storms and their relationship with sunspots over six 11-year cycles (1879–1944) is nearly completed.

Throughout the past year, the time service was operated jointly from the Abinger Magnetic Station and the Royal Observatory, Edinburgh. Preparations have been made for the installation of the equipment from Edinburgh at Greenwich, together with some additional quartz clocks and ancillary equipment.

Considerable progress has been made in the installation of the quartz standards at Abinger, but the majority of the equipment is still in the initial stages of adjustment. The crystal holder of one of the original oscillators installed at Abinger developed a leak early in the year, and has been resealed. Some additional phonic motors have been delivered, including one designed to operate on a 1000 c.p.s. supply and provide, through appropriate gearing, contacts every sidereal second.

The quartz standards at the Post Office Radio Branch Laboratories are still employed to provide a long-term check on the Observatory standards, which have not been in operation for a sufficient time to permit adequate determination of ageing characteristics.

Tape chronographs have been entirely superseded for all intercomparisons between clocks, or between clocks and radio time signals, and electronic methods of measurement are now employed exclusively. For transit records, however, tape chronographs give adequate accuracy, and are retained. Throughout the year 213 observations for the determination of clock error were obtained at the two stations.

Arrangements have been made with the Post Office for the transmission of a short series of dots before the 10.00 and 18.00 hour Rugby time signals to permit measurement of the total lag of the land-lines, transmitter, etc., and readjustment of the phase of the signal transmitting motor, thus permitting a reduction in the scatter of the signals. Reception of American, French and Russian time-signals has been continued as regularly as conditions permit. A new long-wave receiver for the Rugby time-signals designed and constructed at the Observatory has been installed.

The Shortt clocks 66 and 68 which were in use at Abinger have been dismantled and returned to Greenwich. Shortt 61, which was loaned by Mr. H. R. Fry, was of valuable service to the department during the early years of the war, but has now been dismantled and returned.

In order to permit a more thorough investigation of discrepancies which appear to arise between two time-service stations, and to provide a means of accurate intercomparison between the standards at Abinger, Greenwich, the Post Office Radio Laboratories, and elsewhere, a low-power radio-transmitter was set up at Abinger. Frequency comparisons have been carried out regularly, and time comparisons will be undertaken shortly.

An investigator visited Germany in October–December to report on the methods and equipment used for time-service work. A complete quartz clock was obtained from the Physikalische Technische Reichanstalt and has been brought to the Royal Observatory for investigation and test. Arrangements are also in hand for the construction of replica equipment to that used at the Deutsche Seewarte for the control of the Nauen time-signals.

*Nautical Almanac Office.*—Until the end of October, the Office was actively engaged on non-astronomical numerical work for the Admiralty Computing Service; a general account of this work will be published elsewhere. As in previous war years the astronomical work, especially the non-routine work, has been reduced to the minimum compatible with the production of the *Nautical Almanac* and other ephemerides. It has thus again

not been possible to make any substantial progress with the numerous outstanding astronomical investigations—in particular with the publication of the comprehensive *Supplement* and with the occultation programme; now that the extra calls on the staff are almost at an end it is hoped that the war-time arrears will speedily be made up.

In common with all similar printed matter, the routine publications of the Office have suffered lengthy delays, in spite of every effort at expedition, through the shortage of man-power in the printing industry. The computations are generally well up to schedule and "copy" is being sent to the printer progressively earlier each year, but subsequent printing delays still make it impossible to advance the publication dates. Since 1945 January 1 the following publications have been issued:—

| *Publication* | *Published* |
|---|---|
| *Nautical Almanac*, 1946 ... ... ... ... ... | March, 1945. |
| *Abridged Nautical Almanac*, 1946 ... ... ... ... | May, 1945. |
| *Apparent Places of Fundamental Stars*, 1946 ... ... | August, 1945. |
| *Air Almanac* 1945, Part III ... ... ... ... ... | About 6 months in advance. |
| 1946, Parts I and II ... ... ... ... | |

Both the standard and abridged editions of the *Nautical Almanac* for 1947 have been completely passed for printing, but the other publications are not so far advanced.

No changes have been made in the form or content of the above publications and no special publications have been issued during the year. Consideration is now being given to the replies to a circular letter asking for criticism of the *Nautical Almanac* and the proposed *Supplement*. The response has been most encouraging and it is hoped that it will be possible to adopt many of the suggestions made.

For the volume of *Apparent Places of Fundamental Stars* for 1946, the apparent places of the 426 10-day stars normally received from the office of the *Connaissance des Temps* were computed in the Office.

Although the reopening of communications with France has enabled France to supply once again the calculations allotted under international agreement, the collapse of Germany threatened to deny access to the mean and apparent places of stars for 1948 and subsequent years computed by the Astronomisches Rechen-Institut. Accordingly this work was re-allocated among the four other contributing offices and a considerable portion of the work for 1948 (including the whole of that section allocated to U.S.A.) was done before contact was made with Professor Kopff. All the German calculations for 1948 and 1949 have now been received, and it is expected that the Astronomisches Rechen-Institut will be able at least to fulfil these obligations, even if the other work of the Institut cannot be continued. It is most gratifying to record the willingness of the other offices to undertake this additional work, especially in the case of the *Connaissance des Temps*, which has had severe difficulties of its own.

The planning of the revised programme of prediction, reduction and discussion of occultations has again had to be deferred. All the routine work of prediction and reduction is being carried out, but no start has yet been possible with the organisation of the centralised publication or the annual discussion for 1943 onwards. While it is realised that this is most discouraging to observers, it has the compensation that it will enable observations made in occupied Europe during the war, quite a number of which are being received, to be included in the discussions.

Considerable investigatory work has been undertaken, particularly for the Air Ministry, into various instrumental, tabular and graphical methods for astronomical navigation. Little or no change has been made in the navigational publications issued by the Office, though a thorough revision of them is due. The provision of new reduction tables for both surface and air navigation now appears likely, and the design of such tables is being actively considered in relation to the requirements of the Services concerned.

*Royal Observatory, Edinburgh*
(*Director, Professor W. M. H. Greaves, F.R.S., Astronomer Royal for Scotland*)

This report covers the period 1945 May to 1946 February.

The participation of the Observatory in the Greenwich Time Service was terminated at the end of 1946 January. The signals radiated from Rugby at $10^h$ U.T. originated from the quartz clock A1 at Edinburgh up to 1945 December 22, after which date these signals were operated from Abinger. The accuracy of signal transmission referred to in the previous report was maintained, and, in fact, somewhat improved, the mean absolute measured departures of the $10^h$ signals from the times by the clock A1 at which it was intended to transmit them being $\pm 0{\cdot}25$, $\pm 0{\cdot}24$ and $\pm 0{\cdot}25$ milliseconds for the months of October, November and December respectively. These figures include relay errors of feeding the signal on to the line to Rugby, errors of line transmission, errors of radio transmission at Rugby and errors of radio reception and chronographic measurement at Edinburgh. The corresponding contribution to the mean absolute error of individual 24-hour intervals defined by successive signals at $10^h$ U.T. would be $\sqrt{2}$ times the above figures, giving a mean of $\pm 0{\cdot}35$ milliseconds as against the value $\pm 0{\cdot}5$ milliseconds quoted in the previous report. To these errors in individual 24-hour intervals must be added the errors of general trend for which the mean absolute value quoted in the previous report was $\pm 0{\cdot}6$ milliseconds.

During the latter half of 1945 it was noticed that the clock A1 at Edinburgh and the three quartz clocks at the Post Office Radio Branch Laboratories at Dollis Hill all appeared to change their rates, as determined from transit observations, at Edinburgh and Abinger, by about the same amount (about 4 milliseconds per day) at about the same time (the middle of September). This is obviously a matter requiring careful investigation, and is receiving such at Greenwich. It is understood that the same phenomenon has been noticed at other observatories.

An investigation of the errors which affect determinations of time with the Edinburgh Transit Circle has been carried out by Mr. Symms (whose services were on loan from the Royal Observatory, Greenwich) and Miss Penny. They find a marked correlation between the individual clock errors determined on various nights and the measures of collimation error. This shows that erroneous measures of collimation contribute materially to the total probable error of a determination of time. The total probable error of a single night's time determination (using the mean of ten stars) with the Transit Circle is $\pm 20$ milliseconds when personal equations are applied to the results from the several observers. But that part of the whole probable error not due to errors in measuring collimation and level is $\pm 10$ milliseconds or less, this figure including the contribution due to erroneous star places. The impersonal micrometer attached to the Transit Circle is hand driven.

The Time Service equipment was dismantled and returned to Greenwich during February.

The spectrophotometric programme of the measurement of line intensities in early-type spectra, which was suspended at the end of 1940, was resumed in August. The plates are taken with the 36-inch reflector and Hilger spectrograph; they are calibrated with a multiple slit spectrograph and are measured with a Moll-type microphotometer. 39 spectra were secured during the period covered by this report.

*Royal Observatory, Cape of Good Hope*
(*Director, Dr. J. Jackson, F.R.S., H.M. Astronomer*)

*Reversible Transit Circle.*—The observation of standard stars for the zone $-56°$ to $-64°$ begun in 1944 was continued on the same plan. During the year, 6818 transits

and 6748 zenith distances were observed. The following observations were made of bodies in the solar system :—

| | | | | | |
|---|---|---|---|---|---|
| Sun | 148 | Ceres | 11 | Jupiter | 17 |
| Moon | 35 | Pallas | 11 | Saturn | 13 |
| Mercury | 74 | Vesta | 15 | Uranus | 9 |
| Venus | 118 | | | Neptune | 11 |

The reduction of these observations is practically up to date. The preparation of a catalogue based on the observations of 5373 Boss and Backlund-Hough stars made in the years 1936–1944 has been continued. The final positions for 1950·0 have now been obtained by application of the necessary corrections for E–W differences, flexure and pivot errors. The calculation of precession and secular variation is well in hand.

*Zone Observations.*—The work on the reduction of the measures for the zone $-35°$ to $-40°$ was restarted in July. The final positions for the first 4380 stars, i.e. up to $9\frac{1}{2}$ hours of R.A., have been computed; proper motions have also been computed for these stars.

No further work has been done for the zone $-52°$ to $-56°$, but a good deal of work has been done for the higher zones in bringing up the early positions to the epoch 1950·0. As already noted the observation of standard stars for the zones $-56°$ to $-64°$ is being carried out. In the photographic work with the wide-angle lens 40 plates were taken for the zone $-56°$ to $-60°$ and 30 for the zone $-60°$ to $-64°$. The Astronomer Royal has kindly undertaken to have the plates for the zone $-56°$ to $-60°$ measured at Greenwich.

Dr. G. G. Cillié of Stellenbosch has completed the spectral classification of as many stars as possible for the zone $-30°$ to $-35°$ on plates taken at the Harvard branch station at Bloemfontein. About half of the spectrum plates for the zone $-35°$ to $-40°$ have been taken and forwarded to this Observatory.

*Victoria Telescope.*—During the year 2642 plates were taken for parallax and 21 for proper motion on 237 nights. 1822 plates were measured for parallax, 54 for proper motion in declination and 20 for orbital motion. More than 7000 plates remain to be measured. A list of a hundred parallaxes has been published by the Society, and with those in hand the number of stars for which the parallax has been determined since 1926 is now 1431. Papers have been prepared on the selection of stars for parallax determination and on the motions and parallaxes of M-type stars. A paper by Dr. Stoy and Mr. Cormack has been published by the Society on the use of parallax plates for photometry. This includes the determination of the photographic magnitudes of 150 of our parallax stars.

*Photometry.*—During 1945 co-operation with the Radcliffe Observatory has been continued. The plates required to complete the programme for the zone $-35°$ to $-40°$ as outlined in the last annual report were all obtained by Dr. Redman at Pretoria before the end of May. Measurement of these plates is more than two-thirds complete. Towards the end of the year Dr. Redman started observing for a new and slightly longer programme than that just completed. This will provide plates from which the magnitudes of stars in the three zones from $-52°$ to $-64°$ can be derived. It will also include more plates of the E regions, the Pleiades and Southern Eros Stars. These latter plates are intended to clear up outstanding points in the derivation of standard magnitudes and in the reduction of these magnitudes to the International System.

During 1945 Dr. Redman obtained about 90 pairs of plates with the Cape cameras attached to the unfinished 74-inch reflector.

In addition to the routine work on the zone stars, a considerable effort has been expended on improving the existing sequence of standard magnitudes in the E regions. A system of photographic magnitudes based entirely on material obtained at Pretoria has been derived. This system is in excellent agreement with that of the former Cape

magnitudes after the curvature in their scale introduced by the use of diffraction gratings has been corrected in the manner suggested by Dr. Seares in his discussion of the Mount Wilson, Yerkes and Cape Observations of the Southern Eros Comparison Stars. The close agreement between the two systems gives us some confidence that we are now not far from a magnitude system that can be taken as definitive for the range with which we are concerned in the zone work and, thanks to Dr. Seares's work, that this system is not very different from the International System. The photovisual system has still to be investigated.

The Fabry disk photometer attached to the astrographic telescope has been reconstructed to render it suitable for observing bright stars and has been fitted with a number of rotating sectors to reduce the apparent brightness of the brightest stars. A new and improved tube sensitometer to standardize the plates has also been constructed. After a certain amount of experimentation a programme to determine the photographic magnitudes of all stars south of the equator whose HR magnitude is brighter than 5·0 was started in June. The observing is being done by a local amateur astronomer, Mr. H. C. Davies, who volunteered to carry out this very desirable piece of work. To simplify the observing, all stars between declinations $-4°$ and $-64°$ are being observed at a standard altitude of 60°. It is hoped to obtain at least four observations of each star, two when the star is east of the meridian and two when it is west. So far 241 of the 813 stars have been observed. The scale for these magnitudes is determined partly by the reduction constants of the rotating sectors and partly from calibration with the tube photometer. The zero is based on the homogeneous system of visual magnitudes that Dr. Knox-Shaw has developed from the Harvard catalogues, suitably corrected for colour by the application of the colour index appropriate to the spectral type.

The rotating sectors were calibrated under conditions similar to those in which they are used, in a series of laboratory experiments made by Mr. Cousins of Durban during a three-weeks visit to this Observatory in July and August. The values he obtained from two different methods agreed closely with the values derived by calculation from the geometric figures, combined with the assumption that the sectors rotate quickly enough to be regarded as cutting down the incident light rather than the exposure time.

The modified Schilt photometer has been in constant use and has given no trouble whatever. During 1945 just over 74,000 images were measured with it.

*Photoheliograph.*—The Sun was photographed on 290 days; in all 501 plates were taken including 20 for the zero of position-angle. Generally speaking two plates were taken daily throughout the first three and last three months of the year. Of the 75 days on which no plates were taken 56 were in the interval June 26 to August 20 when no plates were available. All the plates which were retained at the Cape because of risk at sea have now been forwarded to Greenwich.

*Occultations.*—The effort to observe all the predicted occultations has been continued. There were in all 113 observations of 58 phenomena. These include 19 observations of 9 stars on October 12 when the Moon passed in front of the Trifid Nebula. Rather more than half of these observations were made at the Observatory by amateur astronomers. The results have been forwarded to the Nautical Almanac Office together with 25 observations made by other amateur observers in South Africa.

There has again been close co-operation with other astronomers in South Africa, both amateur and professional. The co-operation has been specially important in photometry for the determination of standard sequences and in our zone work. Also the determination of spectral types for stars in our zones should add considerable value to the results. Mr. de Kock has continued the active observation of long-period variables in the southern hemisphere, making 3872 observations of 105 stars. Mr. W. P. Hirst has observed double stars with the 7-inch refractor now mounted in the heliometer dome.

Four members of the staff who were away on duties connected with the war returned to the Observatory during the year. The staff is still four short of the full complement.

### *Cambridge Observatory*
### (*Acting Director, Dr. H. A. Brück*)

Photo-electric observations of variable stars and of the planet Uranus with the photometer attached to the Sheepshanks telescope have been continued. To make greater use of this telescope than is possible in photo-electric work which has to be confined to nights with exceptionally good atmospheric conditions, the set-up of the present instrument is being re-arranged in such a way that the telescope may be used on photographic work whenever photo-electric work is impracticable.

In the photometer the potassium hydride cell which has been used so far is being replaced by a cæsium oxide cell so as to make colour photometry over a wide range of wave-lengths possible.

The photographic programme is to be devoted to the determination of proper motions based on the re-observation of Kapteyn areas first photographed about twenty years ago by Smart and Green, and of certain regions first photographed at least forty years ago by Hinks which should provide a set of proper motions of high accuracy and also a good check on the probable errors in Smart's Catalogue of 1928.

Professor F. Rutllant of Santiago, Chile, has taken part in the photo-electric observations. Since October Mr. A. Brown has been engaged on evaluating mean parallaxes from the Cape proper motions.

The results of a comparison between the Harvard and Potsdam systems of spectral classification have been published in the *Monthly Notices*.

### *Solar Physics Observatory, Cambridge University*
### (*Director, Professor F. J. M. Stratton*)

*Staff.*—The Director returned from national service on July 23. Mr. W. Moss, First Senior Observer and Acting Director, retired on August 11 after forty-three years of service with the Solar Physics Observatory at South Kensington and Cambridge. Dr. J. C. Dobbie and Dr. N. B. Slater, observers, have resigned from the staff to take up teaching duties elsewhere. Mr. E. T. Pierce, B.Sc., has been appointed Junior Observer. The three assistants, Messrs. W. H. Manning, L. J. Stanley and T. G. Arthur have returned from national service during the year. Professor F. Rutllant of the University Observatory, Santiago, Chile, has been carrying out spectrophotometric researches on the solar spectrum.

*Buildings.*—Owing to war conditions and the difficulty in securing materials several of the domes have fallen into a condition of disrepair which cannot be rectified till next summer. The telescopes have all been out of commission for lack of staff, but as supplies and necessary replacements become slowly available they are being restored to active service.

*Stellar Work.*—Work on the Cambridge spectrograms of Nova Herculis 1934, interrupted in 1939, has been taken up again.

*Solar Work.*—Dr. Brück and Mr. Moss have communicated to the Society some studies of the relative behaviour of $H\alpha$ and $D_3$ in selected prominences observed with the spectroheliograph. Routine observations with the spectroheliograph were suspended but will be restarted in the coming year. The photo-electric photometer attached to the McClean spectrograph has been used for a number of records of the solar spectrum. The 21-foot Rowland concave grating has been used in a photometric study of Fraunhofer lines in the ultra-violet part of the solar spectrum.

A study of the distribution and movements of prominences through a complete 22-year sunspot cycle carried out by Mr. Moss is in the press.

*Meteorological Physics.*—A new Littrow-type spectrograph with a 60° rock-salt prism is being constructed for work on the solar spectrum in the infra-red, with special

attention to the presence of bands due to nitrous oxide. The spectrum of the night sky is also being studied in the infra-red region.

*University Observatory, Glasgow*
*(Director, Professor W. M. Smart)*

The work on the systematic motions of the stars of the *General Catalogue* continued to progress, although rather slowly.

The instruments have been overhauled, after the inactivity of the war-time period.

Dr. Tannahill has been released from his duties as Flight-Lieutenant, attached to the University Air Squadron.

*University of London Observatory, Mill Hill, and*
*University College Observatory*
*(Director, Mr. C. C. L. Gregory, Wilson Observer)*

*The Radcliffe Telescope.*—At the end of May the 24-inch and 18-inch objectives were removed from the bottom of the hollow pier, the lenses taken from their containing cells, cleaned, reassembled and replaced in the telescope tubes. It was found that a considerable amount of general reconditioning of the telescope was necessary before it could be used. The hydraulic ram which operates the rising floor had become unserviceable and its replacement by an electric hoist was put in hand. An electric motor has been purchased for this purpose and part of the original driving clock of the telescope (which had been replaced by a synchronous motor) is used for a hoist. It is expected that the instrument will be in full working order early in 1946.

*The Wilson Telescope.*—Although this instrument was available during most of the war period it was used only for photographing the spectrum of $\gamma$ Cassiopeiæ to provide a continuous record of any major changes. No large changes have occurred since 1940 November; the measurement and discussion of the plates is in hand.

*Staff and War-Work.*—On 1940 March 25 the Director undertook full-time employment with the Admiralty, and from that date the Observatory workshop was used for various pieces of Admiralty work. In 1940 December the Observatory mechanic, Mr. C. R. Spratt, joined the R.A.F. and, on demobilisation, returned to the Observatory on 1945 December 10. During his absence Dr. E. M. Peachey has acted as caretaker, mainly, however, devoting her time to war-work—mechanical work and instrument-testing for the Admiralty and the Ministry of Supply. As this work increased in importance and more and varied work was required, the Director was released from his Admiralty duties and returned to the Observatory in 1943 October. By 1945 September this work was completed; it included assembling and finishing 260 ranging telescopes and filling 2200 graticules.

The First Assistant, Dr. A. Beer, has been employed on magnetic work at Kew since the termination of his appointment at the Observatory in 1940. The Second Assistant, Major R. W. Pring, R.E., is still serving abroad with a Field Survey Company. It is expected that he will return to the Observatory next April.

*Publications.*—The following were communicated to the Society by the Director: P. C. Chaudhuri, M.Sc., Ph.D., "The Photographic Proper Motions of Stars belonging to the Cluster Præsepe from Plates taken with the Radcliffe Telescope", 1940 March; and E. M. Peachey, B.Sc., Ph.D., "Some Recent Changes in the Spectrum of $\gamma$ Cassiopeiæ", 1942 May.

*University College Observatory.*—Considerable damage by enemy action was done to the observatories and instruments at the College, including the total destruction of the 10-inch Brocklebank reflector. It has been decided by the College authorities that the two small students' observatories in the College courtyard are to be dismantled and such instruments as are still serviceable moved to Mill Hill where, in future, the practical astronomical teaching will be undertaken.

### *University Observatory, Oxford*
### (*Director, Professor H. H. Plaskett, F.R.S.*)

*Staff.*—Dr. Adam was released from Government service at the beginning of the year. Dr. Evans's release coincided with his resignation from the Observatory staff to accept an appointment at the Radcliffe Observatory, Pretoria.

*Work.*—The solar telescope and the spectroscope (in the one-prism form) were brought back into use in April. The Director commenced monochromatic visual observations of the darkening towards the limb of the Sun, using an auxiliary solar image as a comparison source to eliminate variations in atmospheric transmission. Dr. Adam nearly completed a programme for the determination of limb effect and possibly Einstein displacement of a number of lines at the red end of the spectrum. For this purpose she used a Fabry-Perot étalon crossed with the solar spectroscope. The six months of normally good observing weather between April and October gave rather less than the average of cloudless weather, with the result that the programme on limb darkening, which requires long clear intervals, was only one-eighth completed, while the programme on limb effect was two-thirds completed.

### *Norman Lockyer Observatory, Sidmouth*
### (*Director, Mr. D. L. Edwards*)

Mr. D. R. Barber, who had previously been engaged on work of national importance, returned to the Observatory in September and has been appointed Chief Assistant. Dr. G. Alter left the Observatory in November to return to Prague.

Work on the spectrum of $\gamma$ Cassiopeiæ has been continued, also on $\iota$ Herculis which is suspected of short-period changes.

A number of plates of galactic clusters are still available for reduction and will be added to on suitable occasions; the work of reduction, however, is for the time being in abeyance, pending reorganisation of the programme on a peace-time basis.

Regular routine work on gradients and colour temperatures of early-type stars has again become possible, owing to the lessening of war-time difficulties. This work has been resumed on the 12-inch McClean telescope, and a similar programme is being planned on the 9-inch Kensington instrument, using a slightly different technique, with the object of measuring gradients in the blue–ultra-violet region. In connection with this work the measurement of atmospheric extinctions at different wave-lengths is also being planned, and preliminary work on this has been started.

### *Dominion Astrophysical Observatory, Victoria, B.C.*
### (*Director, Dr. J. A. Pearce*)

*Staff.*—Dr. R. M. Petrie and Dr. Andrew McKellar returned to the Observatory in 1945 September after an absence of nearly two years on war duty with the Royal Canadian Navy. On April 1, Mr. W. H. Stilwell resigned to accept an appointment with the Geodetic Service. Professor E. S. Keeping, University of Alberta, spent ten weeks and Dr. H. D. Smith, University of British Columbia, four weeks at the Observatory during the summer.

*Observations.*—The observing weather in 1945 was the poorest in the history of the Observatory, observations being made on 140 nights with 834 observing hours, as compared with the 27-year average (1919–1945) of 196 nights and 1209 observing hours. The number of spectra secured was 1089 as compared with 1285 for an average year.

*Radial Velocity Investigations.*—The observations of the faint Class B stars were continued, with special attention to the Cygnus and Taurus regions. A total of 400 spectra have now been secured of 71 stars of the Pleiades Cluster, practically all members brighter than the 10·5 magnitude.

*Taurus Cluster.*—Mr. W. H. Stilwell measured 231 plates of 17 members of the Taurus Cluster in order to study the reported variability of these stars. Nine stars formerly considered variable were found to have constant velocities.

*Radial Velocity Standards.*—A re-examination of wave-length standards has been in progress for some time, and Dr. R. M. Petrie completed part of the programme in 1945. It is now considered that accurate standards have been obtained for spectral types F5 to K5 for high dispersion (11 A./mm. at $H\gamma$) and moderate dispersion (30 A./mm. at $H\gamma$). The wave-length system is based upon solar wave-lengths as given in the Revised Rowland, and values are chosen so as to reproduce velocities in the solar system and also those of the I.A.U. Standard Velocity stars. The high-disperson table is based upon 92 spectrograms and gives a mean residual Victoria – Standard of – 0·3 km./sec. The moderate-dispersion table is based upon measures of 80 spectrograms and gives a mean residual Victoria – Standard of – 0·4 km./sec. It is felt that these remaining residuals are caused, at least in part, by flexure effects, and investigations are being made to test and evaluate this source of error. The wave-length study has shown very clearly that standards must be derived separately for each dispersion used, at least for solar-type stars.

*Wolf-Rayet Binary HD 193576.*—Professor E. S. Keeping determined the orbital elements of the massive Wolf-Rayet variable HD 193576. The radial velocities were determined by micrometer measurements of 55 microphotograms. Considering the complex character of the spectrum in which wide emission lines of the W6 star are associated with an O6 absorption spectrum, the microphotograms, giving a 20-fold enlargement of the spectrum, gave more trustworthy radial velocities than the usual micrometer measurements of the plates.

*New Measuring Machine.*—Dr. R. M. Petrie has devised a new projector for measuring spectrograms. The principle of the new device is the reduction of the spectrum by optical and mechanical means to a standard dispersion. Micrometer settings upon the comparison lines are unnecessary and the process of reducing the measures is almost entirely eliminated. The radial velocities determined by this new method are accurate, and a great saving of time is accomplished.

*Spectrophotometric Investigations:*

*The P Cygni Stars.*—Dr. C. S. Beals continued his studies of the P Cygni stars. During the year, the main body of data on the stars observable at Victoria has been brought close to completion. These data consist of a discussion on (1) the classification of the stars ranging from type O to type F; (2) the four fundamental types of profiles typical of the P Cygni objects, and numerous variations of the fundamental types; (3) the relatively low intrinsic luminosity of the stars, and (4) their variability in light or spectrum, or both, indicating some lack of equilibrium in the output of energy. Special studies of HD 9974, HD 190603 and MWC 374 were made.

*The Solar-Type Stars.*—From a series of high-dispersion plates of $\alpha$ Persei, Dr. K. O. Wright has measured the intensities of more than one thousand lines. These intensities have been combined with $f$-values derived from a solar curve of growth, to form curves of growth for $\alpha$ Persei. Real differences between the curves for the various atoms appear to exist, indicating (1) the temperatures for neutral atoms is in general higher than those for ionized atoms; (2) the damping factor is always greater for neutral than for ionized atoms, and (3) the turbulent velocities for neutral atoms are always less than those for ionized atoms in this star. These conclusions are in agreement with the concept of a stratification in the atmosphere of $\alpha$ Persei.

*R- and N-type Stars.*—Dr. Andrew McKellar has resumed his research on the $C_2$ bands in the spectra of the R- and N-type stars, which was interrupted by the war. The observational material, comprising about 150 spectrograms of 35 stars, is essentially complete. The primary object of the study is to measure the relative intensities of the 1, 0 main, $C^{12}\,C^{12}$ and isotopic, $C^{12}\,C^{13}$ and $C^{13}\,C^{13}$ bands of the Swan System at $\lambda\lambda$ 4737, 4744 and 4752 respectively. It is hoped to establish whether the relative abundance of $C^{13}$ to $C^{12}$ in the various stellar atmospheres is different from star to star (and different from the 1 to 100 ratio for terrestrial carbon), or whether the observed great strength of the isotopic bands in some stellar spectra may be due to physical conditions other than abundance.

Some by-products of the main study are receiving attention; these are (1) determinations of "rotational" and "vibrational" temperatures from intensities in the *CH* and $C_2$ bands, and (2) an examination of the unidentified blue-green bands which occur strongly in spectra of some of the reddest N-type stars and which were previously studied by Merrill, by Sanford and by Struve.

*Publications.*—The ban on the printing of the Observatory publications imposed by the Government at the commencement of the war is still in effect.

### *Royal Observatory, Helwan*
### (*Director, Dr. M. R. Madwar*)

*Time Service.*—The time service was maintained as usual. The error of the standard sidereal clock Shortt No. 1 was determined from transit observations and rhythmic W/T signals; the number of transits amounted to 22.

Three failures to receive Rugby signals were recorded. Throughout the year no reception was obtained from Bordeaux.

The behaviour of the various clocks was in general satisfactory.

*General.*—Magnetic, seismological, meteorological and solar radiation observations were continued as usual. It was found advisable to publish the magnetic and seismological observations taken at Helwan separately; previously these have been published in the *Meteorological Report, Physical Department.* The first of these reports will contain the observations during 1939.

### *Union Observatory, Johannesburg*
### (*Union Astronomer, Dr. W. H. van den Bos*)

With the 26½-inch visual refractor 723 micrometrical measures of double stars were obtained. With the 9-inch visual refractor 87 occultations have been observed.

Dr. H. van Gent took 421 plates, almost all of 30 minutes exposure time, of variable star fields and a number of comets with the Franklin-Adams Star Camera.

Mr. C. Jackson resigned on his return from Active Service to become Dr. Alden's successor at the Yale Southern Station, Johannesburg. Mr. E. L. Johnson is still on Active Service. Mr. W. S. Finsen continued to render part-time services to the Directorate of War Supplies.

### *Radcliffe Observatory, Pretoria*
### (*Director, Dr. H. Knox-Shaw, Radcliffe Observer*)

The stellar magnitude programme, undertaken in collaboration with the Royal Observatory at the Cape, has been continued. Dr. Redman has finished the photography of the zone $-35°$ to $-40°$, and the plates have been sent to the Cape for measurement. It is proposed to take a similar series of photographs of the zone $-52°$ to $-64°$. Meanwhile new standard *Pg* and *Pv* magnitudes in the E regions at $-45°$ are being determined by a number of methods, including in-focus images calibrated with variable

apertures, rotating sectors or variable exposures, and the Fabry method. Of these the Fabry method has proved the most reliable, and Dr. Redman in collaboration with Dr. Stoy has completed a series of *Pg* magnitudes, believed to be on the international system, with a mean error per star of 0·03 magnitude. To confirm this series a further comparison of the E regions with the Eros stars has been commenced. Similar work on the *Pv* scale is under way, and tests have been made of various methods of development and the colour sensitivities of Ilford Hyperpanchromatic and HP3 plates.

The Director has continued the observation and reduction of occultations and the construction of a system of homogeneous magnitudes for stars south of the equator based on the Harvard photometric magnitudes. The number of occultations observed during the year was 37. This work has now been discontinued, the total number of occultations observed during the years 1939 to 1945 being 308.

The 74-inch mirror and the spectrograph are still unfinished, and the makers have been unable to give any indication of when we may expect to have this equipment and thus be in a position to start on the work for which the Observatory was built. Dr. D. S. Evans has been appointed to the post of Second Assistant, vacant since the death of Mr. E. G. Williams in 1940, but was still at the end of the year awaiting a passage to South Africa.

### *Nizamiah Observatory, Hyderabad*
### (*Director, Dr. Akbar Ali*)

Thirty repetition plates in zones $-17°$ to $-23°$ were taken as usual with the astrographic telescope for proper motion work. Revision of plate-constants in zones $-17°$ to $-23°$ is in progress. The occultations of stars observed at the Nizamiah Observatory in 1945 have been reduced and the results are being communicated for publication in the *Monthly Notices*. The measurements and reductions of the remaining good plates of Eros (1931 opposition) have been begun; thirty plates were measured and their reductions are in progress. The spectrohelioscope was thoroughly overhauled and properly adjusted. The instrument is working satisfactorily and observations of the Sun were made whenever the sky was clear. A new programme of work for the measurement of double stars mainly in the southern hemisphere has been undertaken.

Copies of Volume XIII, Part I, of the *Astrographic Catalogue*, giving the revised values of the plate constants in zones $+36°$ to $+39°$, have been received recently and are being distributed. Volume XII of the series (zone $+36°$) is still in the hands of the printers in England and it is expected that it will be released shortly for distribution.

A. J. Govindraja Mudliar and A. V. Bhima Rao, computers, retired during the year.

### *Kodaikanal Observatory, Madras*
### (*Director, Dr. A. L. Narayan*)

This report embodies data concerning solar activity based on observations made exclusively in this Observatory.

The year 1945 has witnessed a marked increase in all forms of solar activity over the previous year.

The collection of spectroheliograms from other observatories for those days on which incomplete records were obtained here has been resumed, and accordingly 14 positives on film of *Hα* flocculus and 5 positives on film of calcium flocculus for the year 1939 were received from Meudon Observatory, France. 55 original negatives on glass of the photoheliograms for the years 1939 and 1940 were supplied to the Astronomer Royal, Greenwich Observatory. 62 positives of calcium flocculus plates for the last quarter of 1942 and 68 for the third quarter of 1943 were supplied to the Solar Physics Observatory, Cambridge. 105 *Hα* flocculus positives and 24 calcium flocculus positives for the years 1939 to 1944 were supplied to the Meudon Observatory, France.

Daily character figures of solar activity according to *Hα* bright flocculi and absorption markings were communicated to Professor Brunner, Zürich, for inclusion in the *Quarterly Bulletin on Solar Activity*. Daily character figures from calcium flocculi were also worked out and sent to Professor Brunner.

*Observing Conditions.*—During this year, the weather conditions being more favourable than in the previous year, there has been an increase in the number of days of observations. The conditions for solar observations were practically unchanged as in the previous year. The mean value of definition noted in the North Dome before $11^h$ (I.S.T.) was 2·86 on a scale in which 1 is the worst and 5 is the best, as against 2·63 of the previous year; but there were 58 days on which the definition was estimated to be 4 or above, as against 39 of the previous year.

*Photoheliograph.*—Direct photographs of the Sun on a scale of 8 inches to the Sun's diameter were taken on 305 days using a 6-inch achromatic object-glass and a green filter.

*Spectroheliograph.*—Photographs of the monochromatic images of the Sun's disk in K light were obtained on 294 days, prominence plates in K light on 283 days and *Hα* disk plates on 270 days. A total of 1541 spectroheliograms were obtained during the year.

*Six-inch Cooke Equatorial and Spectroscope.*—Visual observations of solar phenomena which could not be readily photographed were continued with this instrument as in previous years.

*Spectrohelioscope.*—Observations with this instrument were made on all days of favourable weather, except on Sundays and public holidays, special attention being paid to the bright chromospheric eruptions and breaking of dark markings. A quarterly list of chromospheric eruptions together with the times of observations was communicated to Professor Brunner of Zürich.

*Research Work.*—The band spectra of the oxides of *Ca*, *Cu*, *Sc* and *Y* have been photographed by the Director in the red and infra-red with a view to identifying these in the solar spectrum.

*Sunspots.*—The following table gives the monthly numbers of new groups observed at Kodaikanal and their distribution between northern and southern hemispheres. The mean daily numbers are also given.

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| New groups | 11 | 5 | 5 | 7 | 13 | 8 | 11 | 5 | 15 | 15 | 10 | 7 | 112 |
| North | 6 | 1 | 2 | 0 | 4 | 2 | 5 | 2 | 6 | 7 | 3 | 4 | 42 |
| South | 5 | 4 | 3 | 7 | 9 | 6 | 6 | 3 | 9 | 8 | 7 | 3 | 70 |
| Mean daily numbers | 1·6 | 0·8 | 1·3 | 2·0 | 2·5 | 2·7 | 2·2 | 1·0 | 2·0 | 3·6 | 2·9 | 1·9 | 2·0 |

When compared with the figures of the previous year, the number of new groups shows an increase of 160 per cent. and the mean daily numbers show an increase of 186 per cent. The Sun's disk was free from spots on 35 days, while the corresponding figure for the previous year was 156, thus indicating that the minimum of spot activity occurred in the year 1944. The approximate mean latitude of the spots was 24°·9 and 25°·7 in the northern and southern hemispheres respectively, being considerably higher than the previous year's figures, due to the high latitude spots belonging to the new cycle. Bright reversals of the *Hα* line on the disk were observed with the spectroscope in the neighbourhood of spots on 10 occasions and dark reversals of $D_3$ line were observed on 13 occasions. Only one displacement of the *Hα* line both ways simultaneously was observed during the year.

*Prominences.*—The year's work is summarised in the Council Note communicated to the Society (see p. 61).

*Time.*—The error of the standard clock of this Observatory was determined mainly by reference to the $8^h\ 45^m$, $13^h\ 30^m$ and $18^h\ 30^m$ (I.S.T.) wireless time signals from Bombay and Greenwich and by occasional observations at the transit instrument.

*General.*—The Committee for the planning of the post-war development of astronomy and astrophysics in India, appointed by the Government of India, with Professor M. N. Saha, F.R.S., as Chairman, and Dr. S. K. Banerji, the Director-General of Observatories, Professor D. S. Kothari, Professor M. Ishaque and Dr. A. L. Narayan as members, met at Kodaikanal to discuss the post-war problems relating to the astronomical and astrophysical observatories in India, particularly for the expansion of the Kodaikanal Observatory. The Committee left for Bangalore for further discussions. The Director of the Observatory attended the Bangalore session of the Indian Science Congress.

*Publications.*—The Annual Report for the year 1944 and the *Kodaikanal Observatory Bulletin* No. 123, "Summary of Prominence Observations for the year 1944", were kept ready for publication.

### *Commonwealth Observatory, Mount Stromlo, Canberra*
### (*Commonwealth Astronomer, Dr. R. v. d. R. Woolley*)

*Time Service.*—Observations for time with a small reversible transit telescope were commenced on 1945 March 8; altogether, determinations of time were made on 168 nights during 1945. The Observatory is in daily communication by land-line with the Postmaster-General's Research Laboratories, Melbourne, where two quartz clocks are maintained. Errors of these quartz clocks are determined by the Mt. Stromlo transit observations. Regular observations are made of overseas radio signals.

*Double Stars.*—A programme of double-star observations with the 9-inch Oddie refractor was commenced on 1945 July 18. During 1945 Dr. Woolley secured 122 observations and Mr. Gottlieb 149 observations.

*Reynolds 30-inch Reflector.*—It is hoped to commence observing with a photo-electric photometer early in 1946, and to start observations of colour temperatures with a slitless spectrograph a little later.

*Theoretical Investigations.*—Dr. Woolley has continued his investigations of the radiative equilibrium of the ionosphere. Dr. Woolley and Dr. Gascoigne have studied Professor Saha's suggestion that uranium fission is responsible for the high excitation of the corona, and concluded that there could not be sufficient neutrons for the process. Dr. Allen has analysed ionospheric and magnetic results to derive the variation of the Sun's ultraviolet light during 1937–44. He has also developed a diffraction theory for the appearance of Fraunhofer lines in the outer corona. Mr. Odgers has carried out theoretical investigations on tides in the Earth's atmosphere and on sunspots.

*Staff.*—Mr. W. B. Rimmer, Chief Assistant, died on 1945 July 2. The present professional staff is as follows: Chief Assistant, A. R. Hogg; Assistants, Dr. C. W. Allen, Dr. S. C. B. Gascoigne, Messrs. H. J. M. Abraham, D. W. N. Stibbs, G. J. Odgers, K. Gottlieb, C. Halliday, D. G. Thomas, B. Dawson. Dr. D. F. Martyn, of the Council for Scientific and Industrial Research, has worked at the Observatory throughout the year. He has been engaged on an investigation of ionospheric theory.

### *Melbourne Observatory*

Astronomical activities have now ceased at this Observatory and the bulk of the equipment has been moved to the Commonwealth Observatory, Canberra. Former correspondents and contributors to the library of Melbourne Observatory are asked to note this change.

*Riverview College Observatory, Riverview, N.S.W.*
*(Director, Rev. D. O'Connell, S.J.)*

Photographic work on variable stars, mainly in or near the southern Milky Way, has been continued. It is hoped that before long difficulties caused by the war, such as shortage of staff, will be overcome and the issue of astronomical publications resumed.

Fifteen occultations, observed during 1945, were partly reduced and sent to the Nautical Almanac Office.

*Sydney Observatory*
*(Government Astronomer, H. W. Wood)*

The programme of work on the *Astrographic Catalogue* has been continued during the year, volumes 18 and 20 having been in the hands of the printer for some months. The programme of transit observations for the *Catalogue* is now complete and reference stars are available for the whole zone. Some "through the glass" plates have been taken with the object of determining proper motions of some galactic clusters in the zone.

The occultations predicted in the *Nautical Almanac* have been observed when possible and reduction carried on in co-operation with the Nautical Almanac Office. The programme of observations of double stars has been continued.

Observations have been made at the request of the Director of the Commonwealth Solar Observatory of right ascensions of GC stars, which transit near the zenith at Mount Stromlo and Adelaide, for use in photographic zenith tube observations.

The civil work consisting of the supply of astronomical information for legal purposes, the time service and answering general inquiries has been carried on. The educational work of the Observatory was continued and lectures and demonstrations on astronomy were delivered regularly.

*Carter Observatory, Wellington, New Zealand*
*(Director, Mr. I. L. Thomsen)*

The Carter Observatory was established by Act of Parliament towards the end of 1938, and began to function in temporary premises formerly known as the Wellington City Observatory in 1939 April. Mr. M. Geddes was appointed Director and Mr. I. L. Thomsen Assistant.

A new building was commenced in 1940 and was officially opened by the Prime Minister, the Rt. Hon. Mr. Peter Fraser. This building consists of two offices, photographic dark rooms, library room, lecture room, spectrohelioscope room, a 20-foot dome for housing the 9-inch photovisual refractor and an 18-foot dome for the proposed 20-inch reflector, the mirror of which was made by the late Mr. J. T. Ward of Wanganui.

In 1942 both members of the staff joined the Royal New Zealand Naval Volunteer Reserve, and Mr. Geddes immediately proceeded overseas. He died suddenly on 1944 July 23 at Glasgow and an obituary notice appears in *Monthly Notices*, **105**, 88. Miss K. Turner was appointed to attend to essential office work during the war, and the Observatory was used by the Meteorological Branch of the Royal New Zealand Air Force as an instruction school.

In 1945 September Mr. I. L. Thomsen was appointed Director with Miss K. Turner as General Assistant.

Prior to 1942 much work had been accomplished in solar observations, the collection of auroral data, double-star measures, occultation observations and photographic work on star clusters. The opposition of Mars in 1939 was carefully observed and the results published in *Popular Astronomy*. During the war the solar work was maintained by the Dominion Observatory.

It is anticipated that similar work will be carried on in future, but definite programmes have not yet been arranged. The Observatory has to undertake a considerable amount of public educational work in astronomy and the time available for the several activities is thus somewhat limited at present.

### *Dominion Observatory, Wellington, New Zealand*
### (*Acting Director, Mr. R. C. Hayes*)

*Astronomy.*—Astronomical work, including daily sunspot observations, was continued until the end of September, when all astronomical activities, other than time service, were again taken over by the Carter Observatory.

*Staff.*—Mr. G. A. Eiby, who spent several years overseas on Air Force Service, returned in October. During his period abroad, Mr. Eiby visited the Royal Observatory, Greenwich.

### *Mr. Robert Barker's Observatory, Cheshunt, Hertfordshire*

The past year was the cloudiest year recorded at Cheshunt, only about fifty nights being suitable for detailed observation.

The lunar walled plain Aristarchus showed further strong developments in the dusky radial bands on the eastern wall. Well-defined dark circles have formed between some of the five bands, and were first seen as difficult objects eight years ago, but are now sometimes as clearly defined as the bands themselves.

Observations of pre-opposition Mars showed the Udon-Ulysses system (longitude 92°) distinctly, and the Nilosyrtis–Protonilus–Deuteronilus (longitude 290° to 360°) appeared as part of a great circle on the Martian disk. The North Polar Cap was at first very extensive and white, with a dark southern rim probably caused through fast-melting snow.

Telescope: 12·6-inch clock-driven Calver equatorial; eyepiece employed ×360 by H. E. Dall.

### *Mr. J. Evershed's Observatory, Ewhurst, Surrey*

The sodium lines in Sun and vacuum tube have been photographed with the liquid prism spectrograph during the first half of the year, and the results, showing variation of wave-length in $D_1$ during three years' work, have been published in the *Monthly Notices*. Measures of the calcium lines H and K in the prominences have been brought up to the year 1939 and published in the *Monthly Notices*.

Experiments have been made with α-bromo naphthalene as a dispersing liquid in one of the three prisms. It has a greater dispersive power than ethyl cinnamate or methyl naphthalene, and when purified and made nearly colourless is found to be very efficient in the red region of the spectrum.

Using all three liquids, spectrum photographs have been obtained of the solar iron lines in the red region, to determine whether they are subject to slight variations of wave-length, as is found for the sodium line $D_1$.

### *Mr. M. B. B. Heath's Observatory, Kingsteignton, Devon*

Daylight observations of Mercury were made on 15 days and 2 drawings made. Daylight observations of Venus were made on 50 days and 12 drawings made. Mars was observed on 6 nights.

Among occasional phenomena observed were the partial solar eclipse (measured greatest phase 0·56) on July 9 and the occultation disappearances of 11 stars in the Præsepe cluster on April 19.

### *Mr. F. M. Holborn's Observatory, Streatham, London*

During the year, 1924 observations were made on 159 nights of 67 variable stars and novæ. The Sun was observed on 206 days for spot counts and naked-eye spots. All records were sent to the British Astronomical Association.

### *Mr. A. M. Newbegin's Observatory, Worthing, Sussex*

The usual routine observations for prominences and sunspots were made and the results for 81 days are as follows:—

Prominences, mean daily frequency = 5·81
Sunspots, „ „ „ = 2·26

Generally, the Sun has remained in a quiet state of activity and no prominences of special significance were recorded, although occasionally some exhibited eruptive tendencies. Sunspots, apart from minor solar flare activity, were very quiet and no flares of intensity 3 were recorded. Many movements of dark flocculi over sunspots were seen, the greatest velocity being of the order of 125 km./sec.

A list of solar flares is in course of preparation and will be sent to M. d'Azambuja for incorporation in the *Bulletin* issued by the International Astronomical Union.

### *Mr. B. M. Peek's Observatory, Solihull, Birmingham*

Routine observations of Jupiter have been continued. During the apparition of 1944–45 the number of longitude determinations of surface features was 2179.

The Thirty-third Report of the Jupiter Section of the British Astronomical Association has been prepared and is in the press.

Five occultations of stars by the Moon were recorded in 1945.

### *Mr. F. J. Sellers's Observatory, Muswell Hill, London*

Telescopic observations of the Sun have been made daily, when possible, since 1945 July. The necessary war damage repairs to the Observatory are nearly complete and it is expected that the spectrohelioscope and other instruments will be in full operation early in 1946.

### *Dr. W. H. Steavenson's Observatory, Cambridge*

In the summer of 1939 the 30-inch Hindle reflector was mounted in the grounds of the University Observatory, Cambridge, by kind permission of the Director, the late Sir Arthur Eddington.

The instrument is covered by a 19-foot dome of light construction, designed by Messrs. H. W. and L. A. Cox, and was first brought into use in 1945 August. Since then it has been regularly employed for the observation of novæ, in continuation of the programme of work interrupted by the outbreak of war.

No observations were made at West Norwood after 1939 August, and the 20-inch reflector used there has passed into other hands.

# REPORTS ON THE PROGRESS OF ASTRONOMY

## THE TIME-SCALE OF THE UNIVERSE

In the nineteen-twenties astronomers were generally agreed that our galactic system, and the majority of the stars within it, had existed in more or less the present form for $10^{12}$ to $10^{13}$ years. As late as 1929 Jeans summarized the views held by most astronomers by stating that "a good many lines of evidence converge in indicating ages of the order of from five to ten million million years for the main mass of the stars . . . and all the nebulæ in the sky may be of the same age".* According to these views the history of the universe of stars and galaxies could be traced backwards for at least one thousand times the accepted value for the age of the solar system ($3 \times 10^9$ years).

Around 1930 it became evident that a complete re-examination of the time-scale problem was in order. The initial impetus was given by the development of the spectacular expanding-universe hypothesis, which led de Sitter† to write as follows in 1932:—

"The temptation is strong to identify the epoch of the beginning of the expansion with the beginning of the world, whatever that may mean. Now astronomically speaking this beginning of the expansion took place only yesterday, not much longer ago than the formation of the oldest rocks on the earth." De Sitter was not prepared to accept the short time-scale derived from the expansion of the universe of galaxies as applying to general stellar evolution. He suggested that the stars and stellar systems might be some thousands of times older than the universe.

The "long" time-scale of the nineteen-twenties ($10^{12}$ to $10^{13}$ years) was based primarily on Jeans's researches on the ages of extended moving clusters and on the statistics of binary orbits. Jeans's studies on the evolution of clusters were made in 1922, several years before the development of the Oort-Lindblad hypothesis of galactic rotation. By 1930 it was clear that the shearing forces of differential galactic rotation would tend to speed up the rate of disruption of at least the less dense clusters. Also there was growing doubt about the validity of Jeans's arguments relating to double stars.

The shift in support from the "long" to the "short" time-scale ($10^{10}$ years $\pm$) came between 1934 and 1937. Early in 1934 Bok‡ demonstrated that the neglected tidal forces of galactic rotation produce a considerable increase in the rate of dissolution of galactic clusters of the Hyades variety. The prevalence of clusters of this type in our galaxy was taken to be in favour of the short time-scale. Jeans's arguments based on the statistics of binary orbits were attacked by Ambarzumian§ and by Kuiper.‖ The general uneasiness with regard to the time-scale and the trend toward the short time-scale are reflected nicely in the discussion on "The Age of the Universe" held by the Society at its March 1935 meeting.¶

In the earlier papers one finds frequent references to the term "age of the universe". In the more recent studies this has been replaced by the term "cosmic time-scale", which implies an attempt at establishing reference posts in the past rather than the fixing of an absolute beginning in cosmic time. The 1936 article in *The Observatory*** concludes with the following paragraph: "The theory of the expanding universe indicates that a catastrophe took place $3 \times 10^9$ years ago, and it is tempting to place the origin of the stars and stellar systems tentatively at the epoch of this catastrophe. We have, in

* *Astronomy and Cosmogony*, 381, 1929. † *Kosmos*, 131, 1932.
‡ *Harvard Circular*, No. 384, 1934; see also *Observatory*, **59**, 76, 1936.
§ *Nature*, **137**, 537, 1936, and *Russ. astr. J.*, **14**, 207, 1937.
‖ *P.A.S.P.*, **47**, 201, 1935.
¶ See the report in *Observatory*, **58**, 108, 1935.
** *Observatory*, **59**, 84, 1936.

our present discussion, apparently touched nowhere the phenomena that took place long before the catastrophe". A similar attitude is found in two excellent recent summarizing articles on the cosmic time-scale, one by Chandrasekhar *, the other by Cecilia Payne-Gaposchkin.† Chandrasekhar suggests the following rational approach to the time-scale problem: ". . . the solution to the problem of the time-scale will ultimately depend on the study of a variety of different aspects of the universe and the establishment in each case of a time interval during which the aspect studied might change to an appreciable extent. And if such studies should lead us in most instances to time intervals which are of the same order of magnitude, it would not be unreasonable to attribute to a unit of time of this order of magnitude a fundamental significance".

What follows is an attempt at a summary of those astronomical observations and deduced correlations which appear to have a bearing on the time-scale problem. In the analysis of the somewhat puzzling observed correlations between red-shifts, distances and numbers of galaxies, we shall not attempt to go beyond the customary expanding universe interpretation. While this makes for simplicity, it might give the false impression of a lack of comprehensiveness. To avoid this, we complete the introductory section with some brief references to the theories of Milne and Birkhoff.

In the Milne theory ‡ a distinction is made between two sorts of time, the kinematical $t$-time of optical phenomena and the dynamical $\tau$-time, which applies to the dynamics of material particles. In kinematical time Milne places the origin of the universe at $t=0$. On this hypothesis the present is represented by $t=t_0$, where in all probability $t_0=2\times10^9$ years. The relation between the two sorts of time is expressed by the formula,

$$\tau=t_0\{\log(t/t_0)+1\},$$

which for $t=0$ yields $\tau=-\infty$. In other words, in dynamical time there is an infinite past. Haldane § has carried Milne's reasoning one step further, and has suggested a way in which galaxies, stars and solar systems may actually have originated. According to this view the galaxies date back in dynamical time to $\tau=-5\times10^{11}$ years. For a discussion of the implications of the red-shift and related phenomena the reader is referred to an article by Robertson ||, which has a useful bibliography, and to recent papers by Coutrez and Lemaître ¶ on the Milne-Haldane theory.

The Birkhoff ** theory of space-time is the latest addition to the field. Since Birkhoff's death it has been developed further by a group of Mexican astronomers and mathematical physicists. It is understood that an analysis of the red-shift and related phenomena by Erro and Graef will appear in print in the near future.

## 1. Meteorites and the Age of the Solar System

Geological evidence, notably that derived from radioactive analysis, shows that the age of the oldest solid rocks on the Earth is about $2\times10^9$ years. Since the Earth was presumably liquid before this time, it has been generally assumed that the probable age of the solar system is of the order of $3\times10^9$ years. Russell has remarked that the existence of radioactive elements with half-periods of the order of $10^{10}$ years points to an upper limit of the order of a few times $10^{10}$ years for the age of the earth and of the chemical elements. This upper limit, which applies presumably to the chemical elements in all the planets, does include the pre-planetary stages of the solar system.

Most of the evidence that has accumulated during the past decade suggests that the majority—if not all—of the meteorites originated in the solar system. It is therefore of

* *Science*, **99**, 133, 1944. † *American Scientist*, **32**, 222, 1944.

‡ See, for example, *Ap. J.*, **91**, 129, 1940; *M.N.*, **104**, 120, 1944; and also a general note in *Nature*, **155**, 135, 1945.

§ *Nature*, **155**, 133, 1945. || *Science in Progress*, Second Series, 1940.

¶ *Ciel et Terre*, **61**, 208, 1945.

** *Physical Review*, **66**, 138, 1944; *Bol. Soc. mat. Mex.*, **1**, Nos. 4 and 5, 1944.

special interest to inquire into the probable ages of meteorites. Delicate age measurements of meteorites by the radioactive (helium) method have been made by Paneth and his associates, most recently in the chemical laboratory at Durham. Paneth has published a brief summary of the present status (1945) of the work in the concluding number of the *Monthly Astronomical News Letter* (No. 36). We quote here some of the principal results and conclusions.

Six iron meteorites were subjected to a careful analysis not only of their helium content but also of their uranium and thorium content. The percentages of uranium and thorium were nearly identical in all six meteorites, but there was a considerable variation in helium content. Paneth considers this as evidence for a considerable range of ages of meteorites (since solidification), roughly from $6 \times 10^7$ to $7 \times 10^9$ years. These conclusions were substantiated by a study of the helium contents only of fifty more iron meteorites.

For a variety of reasons Paneth prefers to consider the above conclusions as provisional. However, we shall have to reckon with the possibility that (1) there exists a large range in the ages of meteorites, and (2) the most likely value for the age of the solar system may in the end prove to be at least twice as great as the value $3 \times 10^9$ years, which has become rather generally accepted.

## 2. Dynamics of Loose Galactic Clusters

In considerations of cluster development in a rotating galaxy one needs wholly different theories for loose and for dense star clusters. For loose streams or clusters, such as the Taurus and Ursa Major clusters, the interaction between the cluster members is relatively unimportant, and the rate of development of this type of cluster is controlled almost entirely by the passage of galactic field stars and by the tidal forces caused by the differential rotation of our galaxy.

Following a suggestion by Oort, Bok * modified Picart's theory † for the dissolution of comets and meteor swarms, so that it would apply to clusters in our galaxy. It was shown that a critical density exists, which for spherically shaped clusters is of the order of 0·10 solar mass per cubic parsec. If the star density in the cluster is less than the critical density, the cluster will be unstable and rapid dissolution will follow. For clusters with average densities in excess of the critical value, the rate of disintegration proves to be much slower than for unstable clusters. The exact value of the critical density depends on the shape of the cluster; it is somewhat greater for an oblate cluster. The quoted density applies to a cluster at a distance from the galactic centre comparable to that of our Sun. The Taurus and Ursa Major clusters are typical examples of loose clusters in the process of disintegration by the galactic tidal forces.

The estimated density of the "Hyades-nucleus" of the Taurus cluster is of the order of 0·25 solar mass per cubic parsec, the total mass being about 150 $\odot$ and the semi-major axes respectively 6, 6 and 4 parsecs. If the interaction between the cluster members is neglected, we find that disintegration of the nucleus by tidal forces and encounters with field stars will take place in between $2 \times 10^9$ and $3 \times 10^9$ years. This disintegration will be speeded up slightly by interaction between cluster members. According to Chandrasekhar ‡, the time of relaxation for the Hyades nucleus is of the order of $10^8$ years, and disintegration from internal encounters alone should proceed in about $10^{10}$ years.

Rather similar conditions are found in the nuclear remnant of not more than a dozen stars in the Ursa Major cluster, but very much smaller average densities apply to the outlying parts of the Taurus and Ursa Major streams. The members of these streams are so far apart that we may safely neglect the attraction of the stream or cluster as a

* *Harvard Circular*, No. 384, 1934; see also a memoir by Mineur in *Annales d'Astrophysique*, **2**, 1, 1939.

† *Dissertation*, Paris, 1892; see also Tisserand, *Mécanique Céleste*, **IV**, Chapter 16, 1896.

‡ *Principles of Stellar Dynamics*, Table 9, 203, 1942.

whole upon its members. The present dispersion in space velocities amounts to probably about 0·5 km./sec. and one galactic revolution hence ($2 \times 10^8$ years, a quantity to which we find it convenient to refer as the *cosmic year*) the stream members will be spread over a volume with a radius of 100 parsecs. Five cosmic years hence ($10^9$ years) the outlying stream members will be unrecognizably lost among the field stars.

The process of disintegration is not far advanced for the Taurus cluster, for which the well-defined nucleus will presumably continue intact for ten to fifteen cosmic years, but for which the outlying members testify that nuclear disintegration is in progress. In the Ursa Major stream we have a cluster in the last stages of disintegration. The disintegration may have begun as long as five cosmic years back, and we have here probably an example of a cluster that has already ceased to exist as a dynamical unit.

Twenty-five years ago the existence of a number of extended star streams, such as the Scorpio-Centaurus, Perseus and Orion streams, seemed to be well established. In 1921 Rasmuson * gave a list of a dozen streams in which the distances between the star-members would have been so great as to make dynamical interaction between the members wholly negligible. Hence none of these purported extended moving clusters could have been expected to remain intact for more than a couple of revolutions of our galaxy.

It would indeed have been an evolutionary puzzle if it could have been established that half of the early B stars actually belong to extended clusters of limited dimensions! Critical analyses published during the past ten years have, however, disposed of the extended moving clusters as separate dynamical units. Smart † has shown that most of the previously noted moving clusters represent sections of large streams of stars partaking in the general star-streaming in our galaxy and with a relatively low dispersion in their linear velocities. Much work remains to be done on the motions of the early B stars, which because of their low dispersion in linear velocities are singularly well adapted for a study of general star-streaming in our galaxy. Researches along these lines may well give us an approach to the study of motions related to the possible spiral structure of our galactic system, but for the present they show no promise of yielding fresh information on the time-scale of our galaxy.

We may summarize the results of this section by stating that ten to fifteen cosmic years represent a significant interval in the dynamical evolution of the known loose galactic clusters.

### 3. Dynamics of Dense Star Clusters

It will be unnecessary to discuss here in detail the evidence for the time-scale of dense star clusters, since this subject was treated in a recent Council Report by Chandrasekhar.‡ It is readily shown that the galactic tidal forces are relatively unimportant for clusters in which the mean density exceeds the critical density for disintegration by a factor five or more. In galactic clusters like the Pleiades, Præsepe, $h$ and $\chi$ Persei, and also in the globular clusters, the gravitational interaction between the stars of a cluster leads to the expulsion of cluster members at a fairly steady rate, with a gradual impoverishment of the cluster as a result. The mechanism of expulsion was first discussed by Ambarzumian § and by Spitzer ||, and more recently it has received a full treatment by Chandrasekhar.¶

For the time-scale problems of dense star clusters the *time of relaxation* of the cluster has great significance. This quantity, which has been variously defined **, is a measure

* *Medd. Lund astr. Obs.*, Series II, No. 26, 1921.

† *M.N.*, **100**, 60, 560, 1940; see also a paper by S. Daro in *Ciel et Terre*, **61**, 266, 1945.

‡ *M.N.*, **105**, 124, 1945.

§ *Ann. Leningrad St. Univ. astr. Ser.*, No. 22, 1938. || *M.N.*, **100**, 396, 1940.

¶ *Principles of Stellar Dynamics*, Chapter V, 1942; *Ap. J.*, **98**, 54, 1943.

** See, for example, Rosseland, *M.N.*, **88**, 208, 1928; Spitzer, *M.N.*, **100**, 396, 1940; and Chandrasekhar, *Principles of Stellar Dynamics*, Chapter II, 1942.

for the time interval in which the orbit of a cluster member will be so affected by close passages of other stars in the cluster that the original orbit bears no resemblance to the new one. Or instead, one can define it as the time needed to re-establish a Maxwellian distribution of velocities in a dense cluster, starting from an arbitrary initial distribution. For a typical globular cluster the time of relaxation appears to be of the order of $10^{10}$ years (fifty cosmic years).

The disintegration of dense clusters proceeds probably as follows. Suppose that a certain star in a cluster has a velocity $v_0$. We can compute the probability that this particular star will acquire in a time $t$ a velocity greater than or equal to the velocity of escape, $v_\infty$, from the cluster. The stars with velocities exceeding the velocity of escape will presumably be lost from the cluster, and the Maxwellian distribution of velocities will be "chopped off" at $v_\infty$. In an interval comparable to the time of relaxation of the cluster, the cumulative effects of close passages of cluster members will tend to restore the Maxwellian distribution of velocities, with the result that a certain fraction of the remaining stars will escape again. Let $t_0$ represent the time of relaxation of a cluster. Chandrasekhar derives then the following relation for the expectation $Q(t)$ that a star will have acquired the velocity $v_\infty$ in a time $t$:—

$$Q(t) = 1 - e^{-0.0075t/t_0}.$$

$Q(t)$ is equal to 0·63 when the exponent equals $-1.00$; Chandrasekhar calls the time thus defined the *mean life* of the cluster. The relation between the mean life ($t$) and the time of relaxation ($t_0$) is therefore

$$t = 133t_0.$$

The significant result from the point of view of the cosmic time-scale is that for the Pleiades cluster the mean life is of the order of $3 \times 10^9$ years (fifteen cosmic years), whereas the value of the mean life for a globular cluster comes out to be of the order of $10^{12}$ years. We conclude therefore that, judged solely from the dynamical side, the globular clusters are very stable aggregations, but that galactic clusters like the Pleiades are relatively short-lived, with a mean life of the order of fifteen cosmic years.

Dynamically all galactic clusters appear to be relatively short-lived organizations. The loose clusters are subject to disintegration by the galactic tidal forces, whereas the denser ones evaporate by internal disturbances. Ten to fifteen cosmic years appear to be a significant time interval in the development of all galactic clusters. The presence of at least several hundred galactic clusters in our galactic system is convincing testimony in favour of the short time-scale of galactic development.

## 4. Statistics of Wide Binaries

The most recent paper on the stability of binary systems is by Chandrasekhar *, who gives a formula for the rate of dissolution of wide binary systems. For conditions like those prevailing for the vicinity of the Sun, Chandrasekhar derives the following formula for the probable time of dissolution in years of a binary:—

$$\tau = 2{\cdot}22 \times 10^{15} \times a^{-3/2},$$

where $a$ is the semi-major axis of the binary orbit in astronomical units. According to this formula, a binary system with $a = 1000$ A.U. will be dissolved (as a result of the cumulative tidal forces from passing stars) in the course of $7 \times 10^{10}$ years, one with $a = 10{,}000$ A.U. in $2 \times 10^9$ years.

On the long time-scale ($10^{12}$ to $10^{13}$ years) one would then expect the observed distribution of semi-major axes for $a = 100$ A.U. to $a = 10{,}000$ A.U. to correspond to

* *Ap. J.*, 99, 54, 1944.

a Boltzmann distribution of the total energies. According to Ambarzumian *, the theoretical frequency function of the semi-major axes would then be of the type:

$$f(a)da = C\sqrt{a}\,da.$$

The observed frequency function is, however, of the type †:

$$f(a)da = \frac{C}{a}da.$$

The observed frequencies for wide pairs are thus far below those predicted on the equilibrium assumption, thus indicating that the dissolution of binary systems has "only just begun".

The trend suggested by Öpik's form for $f(a)$ is also shown in a recent result of Kuiper ‡, who has listed the known binaries within 10·5 parsecs of the Sun. While Kuiper mentions that the volume of space under investigation is rather small for statistical stability, it is significant to note that, in Table 5 of Kuiper's paper, we find 21 systems with $\log a = 1{\cdot}5$ to 2·5, 10 systems with $\log a = 2{\cdot}5$ to 3·5, and 3 systems with $\log a = 3{\cdot}5$ to 4·5. The numbers are too small for a derivation of an approximate form of $f(a)$, but they show an unmistakable trend not unlike the observed frequency function of Öpik. The large numbers of wide pairs, as required on the assumption of the long time-scale, are certainly not present.

The observed distribution function for the eccentricities of binary systems has also figured prominently in controversies relating to the long and short time-scales. According to Jeans §, the observed eccentricities for visual binaries with $e < 0{\cdot}6$ are distributed roughly according to the formula $2ede$. Jeans has shown that this type of distribution function is in agreement with the theoretical function to be expected under conditions of thermal equilibrium, and he has considered this a powerful argument in favour of the long time-scale. Jeans's argument has been attacked first by Kuiper ‖ and later by Ambarzumian.¶ The latter has shown that the observed distribution function would hold not only for the special case of thermal equilibrium, but also for the more general case in which the density in phase space is an arbitrary function of the whole energy of the binary system. The observed frequency function of the eccentricities in visual binaries deserves further study, but at the moment we cannot consider it an adequate argument in favour of the long time-scale.

## 5. Equipartition

Historically the apparent approach to equipartition of kinetic energy for the stars in the vicinity of the Sun has been one of the most powerful arguments in favour of the long time-scale. It was first pointed out by Halm **, and later by Seares ††, that the product of the mass times the square of the velocity is roughly the same for all spectral types, with the notable exception of the B stars, which appear to have only half the amount of the other stars. The most recent evidence on this score has been presented by Vyssotsky ‡‡, who shows that the mean kinetic energy of a group of dwarf M stars, discovered to be dwarfs without previous knowledge of their motions, is about the same as the mean kinetic energy of the A-type stars. It has further been shown by Vyssotsky

* *Russ. astr. J.*, 14, 207, 1937; *Nature*, 137, 537, 1936.
† See also Öpik, *Publ. astr. Obs. Univ. Tartu*, 25, No. 6, 1924.
‡ *Ap. J.*, 95, 212, 1942.
§ See, for example, *Astronomy and Cosmogony*, 306, 1929.
‖ *P.A.S.P.*, 47, 201, 1935.
¶ *Loc. cit.*
** *M.N.*, 71, 634, 1911.
†† *Ap. J.*, 55, 165, 1922.
‡‡ *Ap. J.*, 97, 381, 1943.

and Williams * that the apparent galactic concentration of the F and G stars of the main sequence can be predicted from that of the A stars on the assumption of equipartition of energy perpendicular to the galactic plane. In the 1935 symposium of the Society †, Jeans points to this apparent equipartition of energy as one of the strongest arguments in favour of the long time-scale.

The time of relaxation for the part of the galaxy in the vicinity of our Sun has been variously estimated as $10^{13}$ to $10^{14}$ years. If one accepts the apparent approach to equipartition as produced by the effects of stellar encounters, one is almost automatically led to an age of our galaxy of at least $5 \times 10^{12}$ years. The observational evidence presented in the preceding paragraph is then found to favour the long time-scale.

We have, however, good reasons to doubt if the observed trends are really indicative that stellar encounters have been exerting their smoothing effects over an interval of the order of $10^{13}$ years. For if this were the case, the trend toward equipartition should be universal, regardless of type, rather than limited to special classes of stars. It becomes therefore of importance to search for marked deviations from equipartition. We list some that are typical.

(*a*) As was already noted by Seares, the early B stars mark an exception to the rule; their mean kinetic energies are probably not more than half those of the main sequence stars.

(*b*) The K and M giants have large mean velocities, and their average kinetic energies are in excess of those of the main sequence stars.

(*c*) Special groups of stars show striking differences from the general rule relating to equipartition. As an illustration we may compare the cluster-type variables and the non-variable stars of comparable spectral class. The peculiar velocities of the variable stars (corrected for solar motion, of course) are about five times as large as those of the normal stars of the same spectral class, and, since the masses are presumably comparable, the average kinetic energies differ by a factor 25.

(*d*) Even among the classes of stars that seem to show a tendency to fall in with the equipartition arguments, one notes effects that could hardly exist if smoothing encounters had been operative for as little as $10^{11}$ or $10^{12}$ years. In the case of the A stars, for example, it is evident that there exists generalized star-streaming and that within each stream the dispersions in random velocity are apparently quite small. This is clearly out of line with the equipartition argument.

(*e*) Earlier in this section we mentioned that Vyssotsky and Williams found evidence for equipartition of energy for the A, F and G stars of the main sequence. The authors show, however, that the corresponding mean kinetic energy of the K giants is four times that of the A stars.

It should further be kept in mind that in all arguments relating to equipartition we make use of local solar motion, *i.e.* the solar motion taken with respect to the average for the stars in the vicinity of the Sun. According to the theory of galactic rotation, this solar motion has only limited significance. The small dispersions in the peculiar motions of the B stars, for example, show that these stars move in very nearly circular orbits around the centre of our galaxy. The apparently very large average kinetic energies for the cluster-type variables are, on the other hand, a consequence of the marked degree of asymmetry in the distribution of the motions shown by this class of stars.

It is of interest to pursue this argument one step further. Let us compare the velocity characteristics of the long-period Cepheids and of the cluster-type variables. Judged naively, we find a very much larger mean kinetic energy for the cluster-type variables than for the regular Cepheids. Considered from a general galactic viewpoint, this result is interpreted as indicating that the long-period Cepheids move very nearly in circular orbits around the galactic centre and that the cluster-type variables move in rather elongated orbits. In other words, our problem is reduced to the following:

* *Ap. J.*, 98, 187, 1943. † *Loc. cit.*

Why does there exist a marked correlation between the shapes of the orbits and the lengths of period of Cepheid variables?

The whole problem of equipartition of kinetic energies and deviations from the mean reduces itself to a basic problem of galactic dynamics and of stellar evolution, one that we have hardly begun to recognize as a problem and for which the solution is not yet in sight. Formulated concisely it reads: *How can we explain certain observed correlations between the physical properties of the stars (such as mass, period, spectrum) and their dynamical, or orbital, characteristics in the galaxy?* For the present we can only guess that from these correlations we may ultimately be able to draw important conclusions relative to the cosmic time-scale. We may, however, state with confidence that the equipartition argument can no longer be quoted in support of the long time-scale.

## 6. The Universe of Galaxies

The trend from the long to the short time-scale was initiated by the success of the expanding universe hypothesis. The observed red-shifts in the spectra of the more remote galaxies could be most readily interpreted as caused by true velocities of recession. From the assumption that these recessional velocities had been constant since the beginning of the expansion, it followed that this beginning could be dated at about $2 \times 10^9$ years (ten cosmic years) ago. Subsequent investigations have, however, not entirely upheld this simple interpretation. It is rather ironic that, at a time when the short time-scale is meeting with fairly general support, the evidence from motions and distributions in the universe of galaxies appears rather inconclusive.

The present status of the problem of the expanding universe has been discussed at length by Hubble *, who has expressed the opinion that the simple expanding universe hypothesis is inconsistent with the available observations.

The first inconsistency comes from the red-shifts themselves. The observations for the known clusters of galaxies indicate the existence of a linear relation between the mean value of $\Delta\lambda/\lambda$ and the apparent magnitude of the fifth brightest galaxy in each cluster. In the absence of reliable measures of distances, the assumption is made that the true integrated absolute magnitudes for the fifth brightest galaxy are the same in all clusters under consideration. The average distance for each cluster can then be derived from the formula,

$$M = m + 5 - 5 \log d;$$

but, on the assumption of a true recession, the observed apparent magnitudes will require first a negative correction, which is larger for the more distant than for the nearer clusters. The application of this progressively increasing correction leads to a derived non-linear law for the relation between the velocity of recession and the distance. The rate of expansion increases faster with distance than would hold for a linear law. The simplest interpretation is then that the velocity of expansion is gradually running down. With assumed greater velocities in the past, the derived time interval since the beginning of the expansion comes out to be less than $10^9$ years, which seems far too short to be acceptable.

The second inconsistency found by Hubble refers to the rate of increase of $\log N_m$ ($N_m$ being the number of galaxies per square degree brighter than $m$) with the apparent magnitude $m$. On the assumption of a true recession, the measured apparent magnitudes require again a progressive correction. If this correction is applied, the calculated numbers of galaxies per unit volume are found to increase with distance. This would suggest either a favoured position for our home galaxy, which does not seem acceptable,

* *The Observational Approach to Cosmology*, Oxford, 1937; for a more recent statement see an article in the *American Scientist*, 30, 1942, or the reprint of this article in the *Smithsonian Report* for 1942.

or it leads to an alarmingly small universe with positive space curvature. Neither alternative appears to be especially attractive.

In considering these two basic inconsistencies, one should keep in mind that the observed effects are dangerously close to the limits of observation set by the available telescopic equipment. The adopted magnitude scale from $m = 18{\cdot}5$ to fainter is by no means firmly established and, through relatively small adjustments of scale, it may be possible to remove the stated objections to the expanding universe hypothesis.

In his own analysis of the existing dilemma Hubble has made it clear that there exists no special problem if the observed red-shifts are assumed to have their origin in some unknown principle of physics, rather than an actual expansion. If this interpretation should prevail, the observed red-shifts would not necessarily bear directly on the cosmic time-scale.

The related problems of the red-shift and the distribution of faint galaxies are probably the most important ones of present-day astronomy. At present our relativistic theories are in need of re-examination, and the implications of the Milne and Birkhoff theories have, for example, received so far only insufficient consideration. When the 200-inch reflector goes into operation, it should be possible to extend the observations relating to the red-shift, to check the magnitude system for the faint galaxies and to complete the surveys for the surface distribution to fainter limits. At the present stage of uncertainty it is unwise to claim the evidence from faint galaxies either as in favour of, or as opposed to, the short time-scale.

## 7. Clusters of Galaxies

The study of the dynamics of clusters of stars in our own galactic system has given the most direct evidence in favour of the short time-scale. One naturally inquires if the results of studies of clusters of galaxies have a bearing on the problem of the cosmic time-scale.

One of the best explored clusters of galaxies is that in Virgo. According to Shapley *, the total population of the cluster is close to 200, about 150 spirals and the remainder spheroidal galaxies. The average distance is 2,500,000 parsecs, and the radius of the cluster is of the order of 200,000 parsecs. The dispersion in the peculiar radial velocities (corrected for average red-shift) is of the order of 600 km./sec., according to Mount Wilson observations.†

Unfortunately we possess no dependable information about the average masses of the galaxies which are members of this system. It would be rather surprising if the total mass of the cluster should prove to be much in excess of $10^{12}$ solar masses. It is of interest to compute the dispersion in linear velocity that is found on the assumptions of normal Newtonian gravitational attraction and the virial theorem. For a total mass of $10^{12}$ $\odot$ and a radius of 200,000 parsecs the root mean square velocity is calculated at about 100 km./sec., and the predicted dispersion in the peculiar velocities would then be only 60 km./sec. The discrepancy of a factor of 10 between the predicted and observed values of the peculiar radial velocity can be interpreted either as an indication that the total mass has been underestimated by a factor 100, or that the large observed dispersion in peculiar radial velocity is not produced as a result of gravitational interaction between the component nebulæ. If one is unwilling—as is the author of this Council Note—to accept without further proof a total mass of $10^{14}$ $\odot$ for the Virgo cluster, then the observed dispersion in radial velocity remains a puzzle, and no definite conclusions relative to the cosmic time-scale can be derived from the observations of clusters of galaxies.

Several astronomers have, however, accepted tentatively that the total mass of the

* For a general summary see *Galaxies*, 165, 1943.

† *Ap. J.*, 83, 10, 23, 1936.

Virgo cluster is of the order of $10^{14}$ ⊙.* Assuming the applicability of the virial theorem, Tuberg † has derived times of relaxation of the order of $10^{9}$ to $10^{10}$ years and a half-life of $10^{11}$ to $10^{12}$ years. Tuberg concludes that the presence of several clusters of galaxies gives an *upper limit* of $10^{12}$ years for the time-scale of the universe of galaxies.

Zwicky ‡ has made a careful study of the radial distribution of galaxies in all clusters within reach of the 18-inch Schmidt at Mount Palomar. He has shown that the radial distribution in the Coma, Hydra and Perseus clusters can all be reduced to the same standard curve, that of a bounded isothermal gravitational gas sphere.§ He sees in this a further proof that Newton's law of gravitation operates over distances comparable to the dimensions of the known clusters of galaxies. Zwicky considers the observed uniformity of structure of symmetrical clusters as observational evidence in favour of the intermediate, or even of the long cosmic time-scale.

## 8. Stellar Evolution

The principal sources of stellar energy are in all probability of a subatomic nature. It seems likely that the Bethe ‖-Weiszäcker ¶ cycle accounts for the energy generation in the main sequence stars like our Sun. The central temperatures in the red giants are presumably too low for the carbon cycle to operate and we look here for nuclear reactions involving the lighter elements, such as *D*, *Li*, *Be* and *B*.** To show the interrelationship that exists between stellar evolution and the cosmic time-scale, we begin by quoting briefly some of the conclusions on the evolution of the Sun presented by Russell at the symposium held at the time of the dedication of the Observatorio Astrofisico Nacional de Tonanzintla, Mexico.††

Partly on the basis of previous work by Strömgren and Unsöld, Russell concludes that the most probable composition of the Sun (by weight) is 51 per cent. *H*, 42 per cent. *He*, 1 per cent. *C* and *N*, and 6 per cent. for the remaining elements. Assuming the carbon cycle to be operative at present, as well as in the past and in the future, Russell is led to the following tabular representation for the probable evolution of the Sun:—

| Per cent. of Hydrogen | Spectrum | Abs. Mag. | Time Interval Unit $10^{10}$ Years |
|---|---|---|---|
| 91 | dK8 | +8·2 | (3·9) |
| 81 | dK5 | 7·1 | 5·4 |
| 71 | dK3 | 6·2 | 3·3 |
| 61 | dG8 | 5·4 | 1·9 |
| **51** | **dG2** | **4·7** | **1·0** |
| 41 | F4 | 3·9 | 0·52 |
| 31 | A8 | 3·2 | ·25 |
| 21 | A3 | 2·6 | ·11 |
| 11 | B9 | +2·1 | 0·04 |

The present condition of the Sun is shown in the heavily printed line of figures for 51 per cent. *H*: the spectral type of the Sun is dG2, its absolute visual magnitude +4·7, and, at its present rate of energy loss, the Sun may be expected to change its *H*-content from 51 per cent. + 5 per cent. = 56 per cent. to 51 per cent. − 5 per cent. = 46 per cent. in about $10^{10}$ years. The table shows that if at some time in the past the Sun ever had an *H*-content between 76 per cent. and 86 per cent. that it was, at that time, in all

* Sinclair Smith, *Ap. J.*, **83**, 23, 1936.
† *Ap. J.*, **98**, 501, 1943.
‡ *Ap. J.*, **86**, 217, 1937; **95**, 555, 1942.
§ *Proc. Nat. Acad. Sci.*, **28**, 355, 1942.
‖ *Physical Review*, **55**, 434, 1939.
¶ *Phys. Z.*, **39**, 633, 1938.
** See, for example, Gamow, *The Birth and Death of the Sun*, Chapter VII, 1940.
†† *Scientific Monthly*, **55**, 233, 1942.

probability a dK5 star with $M_{vis} = +7{\cdot}1$; its rate of energy production would at that time have been so low that it would have taken the Sun $5{\cdot}4 \times 10^{10}$ years to pass from 86 per cent. to 76 per cent. *H*. The first entry, in brackets, represents the change from 91 per cent. to 86 per cent.

The last four lines of the table, which represent the post-solar stages of evolution, have an important bearing on the cosmic time-scale. As its hydrogen is transformed gradually into helium, the Sun will probably expand, grow hotter and hence more luminous. The time intervals in successive stages decrease rapidly. Following a brief B-star stage, the Sun would presumably collapse and, upon exhaustion of its *H*-supply, fall back upon its gravitational energy to end as an inconspicuous white dwarf.

Let us suppose for a moment that the long time-scale is the correct one and that the ratios of the numbers of stars in the solar and post-solar stages are represented by the time intervals in the last five lines of the table. Russell shows then that, because of the high intrinsic brightness in the post-solar stage, we would, in all surveys complete to a given apparent magnitude, find at least ten times as many stars in the post-solar stages as in the solar and pre-solar stages. Now it should be kept in mind that the carbon cycle yields a change of mass of at most 0·7 per cent. The observed absence of stars with the spectral types and absolute magnitudes of the last four lines *and with masses nearly equal to that of the Sun* appears to be strong evidence against the long time-scale.

The spendthrift supergiants present a special problem in cosmic evolution. $\gamma$ Cygn, 29 CMaj, $\zeta$ Auri and other stars like them, some of them blue-white, others red, emit energy at a rate in ergs per gram per second which exceeds that of our Sun by a factor of one thousand or more. We have here the dilemma of stars that could be expected to exhaust their supply of sub-atomic energy inside $10^8$ years, half a cosmic year, or less! We are clearly faced with a choice between stars "born" recently, or stars which possess sources of energy very much more powerful than those considered thus far. Nothing short of complete annihilation of matter could keep these stars going at their present rates for a lifetime comparable to the age of our solar system.

We shall see in the section that follows that the current trend in cosmogony is to find a way out of the dilemma by suggesting that highly rarefied stars are still being formed through the process of condensation of matter in interstellar space. While this points towards a possible solution, it is difficult to see how we shall thus be able to understand why so many of the known luminous supergiants are double, some of them even with a white dwarf component (*Mira* Ceti). The supergiants are convincing evidence for the rapidity of cosmic evolution, but we are frankly embarrassed by the fact that they still shine!

The white dwarfs present a different type of problem from the supergiants. They are apparently a final stage in stellar evolution and, on the short time-scale, it is difficult to account for their presence. The suggestion has been made that the white dwarfs are either the products of early collapse, or that they are a species of stars that originated long before the beginning of the present expansion of the universe. Neither hypothesis seems especially attractive. Off-hand the white dwarfs are the strongest available evidence in favour of the long time-scale.

The relation of the white dwarfs to the cosmic time-scale is really a major problem of cosmogony. The researches of Kuiper and Luyten have shown that the average number of white dwarfs per unit volume of space is large enough to make them one of the most common types of objects, excelled in frequency only by the red dwarfs.* It should further be kept in mind that white dwarfs are frequently found associated with "young" supergiants. It is not a comfortable thought to find these oldish-looking stars plentiful and omnipresent in a universe that carries all the marks of youth.

In conclusion we wish to point to two other major problems of cosmogony, which

* See Russell, *Science*, **92**, 26, 1940.

are intimately connected with the time-scale of the universe. The first is that of the origin of the heavy elements, the second that of the non-uniformity of mixing of stars in the universe.

There are at present two conflicting theories to account for the presence and relative distribution of the heavy elements. The first theory, which goes back to some early papers by Sterne * and Weiszäcker † and which has recently been treated more fully by Chandrasekhar and Henrich ‡, considers the present distribution as having been established at the time of the beginning of the expansion, when our universe was small and when enormous temperatures ($10^9$ to $10^{11}$ degrees) and densities ($10^7 \times$ water) prevailed. It is suggested that, with the temperatures dropping as the expansion progressed, at first the heaviest and later the somewhat less heavy elements were "frozen out". At each of the various stages this theory pictures a quasi-equilibrium between the various elements. The second theory takes as its starting-point an explosive character for the beginning of the universe. Its chief proponents are Gamow and Teller.§ These authors suggest that the heavy elements originated as the product of a general breaking down of very much heavier elements, in other words through nuclear fission.

For many years astronomers have known that the appearance of the Russell-Hertzsprung diagram was by no means the same for all parts of the universe. The most striking first evidence came from studies of clusters, notably by Shapley and by Trumpler. || The importance of the dual character of the distribution was stressed more recently by Shapley in his talk before the eighth annual Washington conference of theoretical physics.¶ There are indications for the existence of wholly different distribution patterns for the central and outer regions of galaxies, or for globular and galactic clusters.

The general prevalence of two basic types of distribution patterns has been demonstrated most dramatically in a recent paper by Baade **, in which it was reported that the central region of the Andromeda Nebula, and the companion nebulæ M 32 and NGC 205, had actually been resolved into stars. The customary Russell-Hertzsprung diagram for the vicinity of the Sun has its luminous O and B stars, very few F giants and many K and M giants with $M_{pg} \sim +1$ to $+2$. It is characteristic for the outer regions of spirals and for galactic clusters; Baade refers to this pattern as Type I. Baade's Type II has the familiar steep slope of the giant branch in globular clusters. The absence of supergiants and of normal O and B stars is a notable feature; Type II distributions are apparently characteristic for the nuclei of spirals, for the amorphous ellipsoidal galaxies and for systems of galaxies of the Sculptor and Fornax variety. The study of the cosmogonical significance of these two types of distribution patterns may well provide the answers to some of the questions which were raised at the end of Section 5 of the present paper.

## 9. Interstellar Matter

In the years to come we may look forward to increasing emphasis on the study of the physics of matter in interstellar space. Since 1920, observers have been gathering observational evidence relating to temperatures, densities, degrees of ionization and distribution of the interstellar gas. For the past fifteen years many astronomers have worked on the problems of temperatures, numbers, sizes and kinds of particles of cosmic dust. There is beginning to emerge a general picture of physical conditions in inter-

* *Trans. electrochem. Soc.*, **68**, 1935; *Harvard Reprint*, No. 114, 1935.
† *Phys. Z.*, **39**, 633, 1938.
‡ *Ap. J.*, **95**, 288, 1942.
§ See, for example, *J. Wash. Acad. Sci.*, **32**, 353, 1942; or *Science*, **95**, 579, 1942.
|| See, for example, Shapley, *Star Clusters*, Chapter III, 1930.
¶ *Science*, **95**, 579, 1942.
** *Ap. J.*, **100**, 137, 1944.

stellar space, and there have already been some first attempts at a cosmogonical analysis of the data. It is becoming evident that the cosmic time-scale will play as important a part in interstellar cosmogony as in the stellar field. While it is yet too early to quote definite conclusions, it may be of value to outline briefly some of the key-problems in which the time-scale is a factor.

The principal cosmogonical problem for interstellar space is an inquiry into the process of growth of interstellar particles. How can we picture these particles as having originated, and how can we account for their present deduced dimensions? The questions were first asked by Lindblad *, who suggested that the observed particles could be accounted for as a result of a continuous process of growth by condensation over an interval comparable to the short time-scale. Lindblad's ideas were developed more fully by Jung †, and quite recently they have been the subject of a comprehensive study by Oort and his associates ter Haar, van de Hulst and van Woerkom.‡

Jung was the first one to draw attention to the possible influence of electrostatic charges of the growing particles. According to Jung, each metallic particle will assume a positive charge, as a consequence of photo-ionization. The impinging protons will be repulsed by the positively charged particles and the rate of growth will be less than for uncharged particles. The effect is so pronounced at densities of the order of $10^{-26}$ gm./cm.$^3$ that Jung expects no perceptible growth for an average element of interstellar space. For densities of the order of $10^{-22}$ gm./cm.$^3$, which are probably typical for some of the denser dark nebulæ, rapid particle growth will however occur, with, according to Jung, the probability that particles with masses of the order of $10^{-15}$ gm. will be formed in $10^5$ years. The densities in some of the best-known dark nebulæ may be of this order, and it is not impossible that higher average densities existed at the earlier stages in the expansion of the universe.

Jung's conclusions about the particle charges have been challenged by Spitzer§, who shows that collisions with fast-moving electrons will build up negative charges faster than the positive charges produced by photo-ionization. Spitzer finds that $-2$ volts is the most probable value for the negative charge of an average interstellar particle. Spitzer's results have been confirmed by van Woerkom, who finds a somewhat larger negative charge for particles in Strömgren's *H*II (ionized hydrogen) regions than in the *H*I regions, where most of the hydrogen is neutral.

Ter Haar and van de Hulst give the following general scheme for the formation and growth of interstellar particles. At fairly low densities interstellar molecules are formed, first of two, then of three and later of more atoms. The condensation nuclei, which are thus produced, will grow through collisions with ions; van de Hulst shows that the growth comes chiefly from heavy ions rather than from free hydrogen or helium. The calculated rates of growth are quite high. Particles with radii of the order of $10^{-5}$ cm. may be built up in $3 \times 10^7$ years; the slowest permissible rate produces the observed radii in $2 \times 10^9$ years.

From the published material one would therefore deduce that the observed relative distribution of gas and dust in our galaxy can best be understood if one accepts the short time-scale for the universe. It would be difficult to understand on the long time-scale how so much of the gas could possibly have escaped capture by the solid interstellar matter.

However, it is still too early to accept these conclusions as final. The uncertainties in the data of observation and in the deductions about present physical conditions in

* *Nature*, **135**, 133, 1935.

† *A.N.*, **263**, 426, 1937; see also the summary by Schoenberg in *Ergebn. exakt. Naturw.*, **19**, 1940.

‡ *Ned. Tijdschr. Natuurk.*, **10**, 238, 1943; see also ter Haar's paper in *Ap. J.*, **100**, 288, 1944; or *B.A.N.*, **10**, 1, 1943.

§ *Ap. J.*, **93**, 369, 1941.

interstellar space are obvious to everyone working in the field. To this we must add that our present knowledge about the physics of particle growth is still very incomplete.

In an as yet unpublished investigation, Cernuschi, at Harvard, shows that there are many weak points in the processes of particle growth described above. His principal criticisms are concerned with the charges of the elementary particles and the calculated rates of particle growth. Cernuschi shows that it is not necessarily very probable for a colliding ion or atom to "stick" to an elementary particle, in spite of the fact that the particle will be at 3° K. and that the ion or atom may have a speed corresponding to 10,000° K. Analogies to "freezing" and to "supersaturation" have no significance when it comes to processes involving a particle and a single colliding atom or ion. Cernuschi bases his analysis on a modification of the theory of adsorption of gases by surfaces, and on some experimental results related to the reflection of electrons by metallic surfaces.

In the past most laboratory research has dealt with the capture of relatively cool gas atoms by hot filaments. It would probably not be difficult to realize in the physical laboratory conditions resembling those of interstellar space, but so far this has not been done. It would be unwise to claim interstellar support for the short time-scale until some of the above difficulties have been further explored.

We have so far been concerned mostly with the evidence about the time-scale derived from considerations of particle growth. We turn now finally to the isolated dark nebulæ and inquire briefly into the problems of the stability of isolated dark nebulæ and the related question of the formation of stars from cosmic clouds of gas and dust.

Klauder * was the first to attack the problem of stability of dark nebulæ. He showed that most dark nebulæ are unable to withstand the disruptive effects of diffusion and of the galactic tidal forces, with the result that for most clouds disintegration follows inside $10^8$ years. Only the more massive clouds have a chance of being held together for intervals comparable to the short time-scale.

The problem of the cosmogonical status of relatively dense and well-bounded clouds of interstellar dust is beyond question the leading one to-day. We found in the preceding section that we are almost forced to accept the probability that stars are still being "born" or, at least, that some supergiants came into being less than $5 \times 10^8$ years ago. Is it possible that in the Southern Coalsack we have an example of a star, or group of stars, about to be formed? Or are some of Barnard's small dark objects future stars? These questions, and others like them, were first asked many years ago when Barnard and Wolf published their excellent photographs of dark nebulæ in our Milky Way and in H. D. Curtis's discussion of the significance of dark lanes in spirals seen edge-on. Quite recently Spitzer and Whipple have again attempted to formulate some of the basic theoretical problems that will need to be solved before we can expect to give comprehensive answers to some of these questions.

Spitzer † has contributed two effects which seem to favour condensation. In the first-quoted paper, he shows that the mutual screening by two elementary particles may produce an attractive force between the particles, under certain conditions more than two hundred times as large as their mutual gravitational attraction. In the second of the quoted papers, Spitzer finds that interstellar matter tends to concentrate very markedly toward the central plane of a galaxy and that the dark central bands observed in many galaxies may represent highly condensed dark matter.

Spitzer's ideas were elaborated in a paper presented by Whipple at the symposium during the dedication of the Observatorio Astrofisico Nacional de Tonanzintla, Mexico (unpublished, 1942). Whipple assumes the presence of a Coalsack-like dark nebula in an isotropic radiation field. He shows that a small condensation will tend to be

* *A.N.*, **262**, 233, 1937.
† *Ap. J.*, 94, 232, 1941; 95, 329, 1942.

"kneaded" by the radial pressure exerted from outside and that, aided by the object's own gravitational attraction, a rarefied star will emerge in about $10^8$ years.

Whipple's result is at best a preliminary one. Many other factors will need to be reviewed. For objects with diameters of the order of five parsecs or more, the process of accretion studied by Hoyle and Lyttleton * will have to be taken into account. The co-existence of gas and dust will have to be investigated more fully, especially since Adams † has shown that multiple interstellar lines are commonly observed. Also the simple first assumption of isotropic external radiation pressure should be modified, with the possibility being kept in mind that one or more near-by O and B stars may exert more effective radiation pressure than the entire galactic field. The stage appears to be set for some major advances in the theories of stellar evolution and cosmogony. We are sure to gain from these studies a deeper insight into the problem of the time-scale of the universe.

## 10. Conclusion

In our summary of the present status of the time-scale of the universe we have found mostly indications in favour of the short time-scale (3 to $5 \times 10^9$ years). The strongest evidence is contained in the second, third and fourth Sections of this Council Note (clusters and binaries). The evidence derived from data on the universe of galaxies is not conclusive at the moment, and will probably remain indefinite until the questions about the expansion of the universe are settled. The field of stellar evolution is in a state of flux, but we find almost everywhere signs of youthful exuberance, notably among the supergiant stars. In cosmogonical studies of interstellar space we are now at the critical time where it appears possible to formulate tentatively several basic evolutionary problems related to the cosmic time-scale.

All told it appears unlikely that we shall soon be permitted a return to the comfortable and spacious long time-scale of cosmic evolution.

BART J. BOK.

* *Proc. Camb. phil. Soc.*, **35**, 405, 592, 1939; **36**, 424, 1940; see also Bondi and Hoyle, *M.N.*, **104**, 273, 1944.

† *Ap. J.*, **97**, 105, 1943.

## SOLAR ACTIVITY

*Sunspots.*—The first recorded signs last year of rising activity after the solar minimum (now given by Zürich as 1944·2) have now turned into a fairly steep rise that should culminate in a solar maximum about 1948. The provisional mean "sunspot number" for 1945 is 32 compared with 10 for 1944. As not infrequently happens, the monthly mean sunspot numbers, though generally increasing during the year, showed wide variations. After rising to 45 in July then falling and rising to 64 by October, the sunspot number for December fell back to 27. During 1945, the distinctive features of solar minimum were fast disappearing. For instance, spotless days were few, and the equatorial spots of the old cycle were less than 5 per cent. of the total number of spots, the bulk of which ranged in latitude from 15° to 35°. However, only one of eleven solar flares observed at Greenwich rose to intensity 3. Four radio fade-outs, which usually correspond to flares either of intensity 2 or 3, were reported by Cable and Wireless Limited. One of these fade-outs recorded on March 20 ($8^h$ $45^m$ to $9^h$ $40^m$ U.T.) synchronized approximately with a solar flare of intensity 2 not fully observed, but seen as the base of an eruptive prominence at the Sun's east limb.

Eleven small geomagnetic storms were recorded at Abinger in 1945 as compared with nine in 1944, including one "great" storm. Sequence disturbances at intervals of 27 days that were a notable feature from about the middle of 1942 to 1944 May were, however, absent; in fact, at no time during the recently ended minimum were magnetically "quiet" days so numerous as during certain epochs of 1945. As an offset to these quiet epochs, there were the eleven storms already mentioned and several "sudden-commencements" independent of them.

Of individual sunspot groups, two exceeded in area 1000 millionths of the Sun's hemisphere, namely those with respective central meridian passage on May 1·5 and September 23·6, both in latitude 18° S. Other groups reaching or exceeding 500 millionths crossed the central meridian on the following dates:—

March 8·8, March 28·2, April 1·2, July 15·1, October 3·9 and October 4·0.

The first of these groups was associated with a solar flare observed at Mount Wilson on March 10; a small geomagnetic storm began 40 hours later (there was minor disturbance on March 11).

An interesting group of four prominences, connected with one another by streamers and rising above two adjacent spot-areas on January 2–4, is described in *P.A.S.P.*, **57**, 97, 1945. As part of this prominence formation, a "coronal" prominence formed above one of the spot-groups. Streamers flowed from this, not into a sunspot as is usual in such cases, but into one of the adjacent prominences.

H. W. NEWTON.

*Prominences.*—The year 1945 has witnessed a marked increase in all forms of solar activity.

The mean daily areas and numbers of calcium prominences as derived from Kodaikanal photographs are as follows:—

| | *Areas* | | | *Numbers* | | |
|---|---|---|---|---|---|---|
| | North | South | Total | North | South | Total |
| January to June | 1·36 | 1·25 | 2·61 sq. mins. | 4·68 | 4·39 | 9·07 |
| July to December | 2·00 | 2·21 | 4·21 „ | 5·40 | 5·37 | 10·77 |

When compared with the figures of the previous year, there is a marked increase in both areas and numbers, the former being 58 per cent. and the latter 30 per cent. The areas showed a preponderance in the southern hemisphere as in the previous year, but the numbers show a southern defect.

The distribution of the areas in latitude shows maximum activity between 45°–50° both in the northern and southern hemispheres. The distribution in numbers shows a maximum activity between latitude zone 46°–50° in the northern hemisphere and between 51°–55° in the southern hemisphere.

Six metallic prominences were observed during the year. Of these, two were in the northern hemisphere and four in the southern hemisphere.

Ninety-one displacements of the hydrogen C line in the chromosphere and prominences were observed during the year with the spectroscope as against eighteen during the previous year. Of these, thirty-one showed displacement towards violet, forty-five towards red, and fifteen showed displacement both ways simultaneously. The largest displacement observed during the year was 4·5 A. both ways on September 6.

One hundred and forty-five displacements in prominences were observed with the spectrohelioscope as against twenty-five during the previous year. Of these, fifty-two were in the north and ninety-three were in the south, while eighty were in the east and sixty-five in the west. Seventy-seven showed displacement towards red, sixty-seven towards violet, and one showed displacement both ways simultaneously.

A long filament-type prominence of height 4′ and base only 1° in the east limb of the Sun was photographed on February 13. A large prominence, base extending from +2° to −54° in the east limb, of height 2½′ and covering an area of 3 square minutes, was photographed on January 5. Another prominence, base extending from +42° to −15° in the east limb having an area of 4 square minutes, was photographed on April 19.

The mean daily areas of hydrogen absorption markings (without applying foreshortening correction) was 2123 millionths of the Sun's visible hemisphere, showing a marked increase of 105 per cent. over the previous year. This is mainly due to the appearance of large markings towards the end of the year. The distribution in areas shows an increased activity between the zones of latitude 30°–35° and 50°–55° in the northern hemisphere, while in the southern hemisphere the activity is mainly confined to the latitude 35°.

A. L. NARAYAN.

## COMETS

Since the last report on comets four new comets have been discovered and four periodic comets have been detected. Comet Berry, which was discovered on 1944 September 13, was seen again on September 16, but no further observations were obtained owing to the unfavourable position of the comet, and it was therefore impossible to compute an orbit.

Dutoit discovered a comet on April 9, magnitude 10, but the comet was not seen again.

Comet Dutoit (1945 *d*) was discovered by Dutoit on June 11. Its magnitude at the time of discovery was 10, and as it was receding from the Sun, and shortly afterwards from the Earth also, it did not become a conspicuous object.

Comet Friend-Peltier was discovered by Mr. Clarence L. Friend of Escondido, California, on November 22, and independently by Mr. Leslie Peltier of Delphos, Ohio. Its magnitude was estimated to be 8 but no definite positions were given at the time. Later positions enabled an orbit to be computed from which it appears that this comet makes a fairly close approach to the Sun—less than 0·2 astronomical units.

Comet Pons-Winnecke was found by Giclas of the Lowell Observatory close to the position predicted in the *Handbook*, *B.A.A.* A correction to the *Handbook* perihelion of 2·6 days was indicated. From observations of this comet made in June, July and August an orbit was computed by J. Bobone. The elements of this orbit are given,

together with those given in the *Handbook*, but it should be noticed that Bobone's elements refer to the equinox of 1945·0. As this comet passed within 0·6 astronomical units from Jupiter considerable perturbations were caused. A definitive orbit was computed by members of the Computing Section of the B.A.A. and it was very satisfactory that the comet was found so close to its predicted place. A meteor shower from Pons-Winnecke was well observed in 1916 June and it is possible that it will also be seen in 1946. In 1927 this comet came within $3\frac{1}{2}$ million miles from the Earth. Only one other comet has made a closer approach than this—comet Lexell in 1770 coming within $1\frac{1}{2}$ million miles from the Earth. Although comet Pons-Winnecke suffers considerable perturbations, it has continued its regular course for more than a century and offers a remarkable contrast to some of the short-lived comets.

*Elements of the Orbits of Comets*

| Comet | $T$(U.T.) | $\omega$ | $\Omega$ | $i$ |
|---|---|---|---|---|
| | | ° ′ ″ | ° ′ ″ | ° ′ ″ |
| Dutoit 1945 *d* | 1945 May 17·134 | 280 08 00 | 254 18 00 | 156 30 00 |
| Pons-Winnecke | 1945 July 10·58625 | 170 06 29·6 | 94 20 39·1 | 21 43 39·1 |
| | 1945 July 10·62 | 170 06 11·0 | 94 26 53·0 | 21 42 07 |
| Kopff 1945 *b* | 1945 Aug. 9·54 | 29 48 00·0 | 254 54 58·0 | 7 10 19·0 |
| | 1945 Aug. 11·27523 | 31 32 49·9 | 253 02 34·9 | 7 13 25·9 |
| Friend-Peltier | 1945 Dec. 17·282 | 216 43 00 | 325 24 00 | 49 29 00 |

## DOUBLE STARS

*Measures.*—Reuyl (*A.J.*, **51**, 181) gives photographic measures of BD + 19°5116; Mitchell, Beddow and Watson (*A.J.*, **51**, 184) photographic measures of three double stars.

*Orbits:*

| Double Star | $P$ | $e$ | $a$ | Computer | Reference |
|---|---|---|---|---|---|
| | y | | ″ | | |
| ADS 61 | 106·83 | 0·450 | 1·43 | Baize | *l'Astr.*, **57**, 44 |
| ,, 1598 | 62·26 | 0·360 | 0·678 | Baize | *Bull. Ast.*, **12**, 7 |
| ,, 1631 | 374·03 | 0·629 | 1·39 | Arend | *B.A.B.*, **3**, 205 |
| ,, 1737 | 150·0 | 0·71 | 0·496 | Baize | *J. Obs.*, **26**, 93 |
| ,, 2446 | 108·05 | 0·68 | 0·52 | Baize | *J. Obs.*, **26**, 93 |
| ,, 3098 | 206·3 | 0·316 | 0·457 | Arend | *B.A.B.*, **3**, 245 |
| ,, 5234 | 118·0 | 0·70 | 0·86 | Baize | *l'Astr.*, **56**, 157 |
| ,, 6762 I | 241·4 | 0·372 | 0·569 | Arend | *B.A.B* **3**, 176 |
| ,, 6762 II | 452·0 | 0·318 | 0·739 | | |
| ,, 7114 | 39·0 | 0·39 | 0·68 | Baize | *l'Astr.*, **56**, 104 |
| ,, 7744 | 276·18 | 0·409 | 1·492 | Arend, Sanders | *B.A.B.*, **3**, 152 |
| ,, 8419 | 120 | 0·63 | 0·35 | Baize | *l'Astr.*, **58**, 82 |
| ,, 9397 | 10·50 | 0·70 | 0·213 | van den Bos | *M.N.A.S.S.A.*, **4**, 3 |
| ,, 9909 | 45·69 | 0·740 | 0·720 | Baize | *l'Astr.*, **56**, 157 |
| ,, 10087 | 129·5 | 0·626 | 0·95 | Baize | *J. Obs.*, **24**, 123 |
| ,, 10360 | 8·04 | 0·91 | 0·210 | Eggen | *P.A.S.P.*, **57**, 205 |
| ,, 10585 | 64·3 | 0·23 | 0·61 | Baize | *J. Obs.*, **26**, 94 |
| ,, 11871 | 59·80 | 0·24 | 1·26 | Baize | *J. Obs.*, **26**, 95 |
| ,, 12145 | 59·02 | 0·53 | 0·36 | Baize | *J. Obs.*, **26**, 96 |
| ,, 12972 | 144·0 | 0·123 | 0·585 | Baize | *Bull. Astr.*, **12**, 7 |
| ,, 14360 | 155·17 | 0·424 | 0·786 | Baize | *J. Obs.*, **26**, 97 |
| ,, 15972 | 44·786 | 0·4086 | 2·395 | Baize | *l'Astr.*, **58**, 83 |
| $0^h\ 27^m{\cdot}0\ -63°$ | 43·07 | 0·770 | 0·411 | Hirst | *M.N.*, **105**, 36 |
| $6^h\ 53^m{\cdot}7\ -35°$ | 16·70 | 0·3832 | 0·216 | Hirst | *M.N.*, **105**, 38 |
| BD +45° 2505 | 12·5 | 0·71 | 0·685 | Baize | *l'Astr.*, **58**, 62 |

*B.A.B.* = *Bulletin Astronomique de l'Observatoire Royal de Belgique.*

## COMETS (*continued*)

Comet Kopff was found from the ephemeris in the *Handbook, B.A.A.*, by Giclas, Lowell Observatory. From observations made from June 5 to August 9, J. Bobone computed an orbit which appears in the list beside the orbit given in the *Handbook*. Bobone's elements refer to the equinox of 1945·0.

Comet Väisälä (1944 *b*) was located by Van Biesbroeck as a diffuse object of magnitude 15·5 on two plates taken with the 24-inch reflector of the Yerkes Observatory on August 7 and 8.

Comet Oterma 3 (1943*a*) was also located by Van Biesbroeck on two plates taken on April 14 with the 82-inch reflector of the McDonald Observatory. The magnitude of the comet was given as 17.

*Observed during part of 1944 and 1945*

| Comet | *q* | Period (years) | Equinox | Computers | References |
|---|---|---|---|---|---|
| Dutoit 1945 *d* | 0·9979 | ... | 1945·0 | 2 | *I.A.U. Circ.*, 1010 |
| Pons-Winnecke | 1·15966 | 6·2344 | 1945·0 | 2 | *H.A.C.* 725 |
| | 1·15997 | 6·1497 | 1950·0 | 4, 6, 7, 8 | *Handbook, B.A.A.*, 1945 |
| Kopff 1945 *b* | 1·49376 | 6·1928 | 1950·0 | 1 and 5 | *Handbook, B.A.A.*, 1945 |
| | 1·49574 | 6·1900 | 1945·0 | 2 | *I.A.U. Circ.*, 1019 |
| Friend-Peltier | 0·1945 | ... | 1945·0 | 3 | *I.A.U. Circ.*, 1023 |

Computers: 1, W. E. Beart; 2, J. Bobone; 3, L. Cunningham; 4, C. Dinwoodie; 5, W. P. Henderson; 6, K. Pollock; 7, J. G. Porter; 8, M. Sumner.

M. DAVIDSON.

## DOUBLE STARS (*continued*)

*Miscellaneous.*—Wallenquist (*Ark. Mat. Astr. Fys.*, **31**A, No. 16) gives a second list of photometric observations of double stars. Aitken notifies the transfer of his Card Catalogue to the Lick Observatory (*P.A.S.P.*, **56**, 249) and writes on early double star work at Lick (*P.A.S.P.*, **57**, 138). Olivier writes a summary on double stars (*P.A.*, **52**, 417). Ellison (*J.B.A.A.*, **54**, 169) has a note upon the measurement of double star position-angles near the pole. Van den Bos (*Monthly Notes Ast. Soc. South Afr.*, **4**, 3) writes on visual binaries with known periods and small observable arcs; Hirst (*ib.*, **4**, 28) gives a note on this paper. Alden (*A.J.*, **51**, 96) has a note on the mass ratio of $\mu$ Orionis. Van de Kamp and Lippincott (*A.J.*, **51**, 162) give a photographic determination of parallax and mass ratio of $\delta$ Equulei.

W. H. VAN DEN BOS.

## ADDRESS

*Delivered by the President, Professor H. H. Plaskett, on Astronomical Telescopes*

*Introduction.*—This is the first Annual Meeting for six years that has not been held under the shadow of war. Our rejoicings at peace and at the resumption of astronomical research are not lessened by the fact that our Society has throughout the whole of these dark years not only maintained its activities almost unimpaired but has also branched out in new directions. The *Monthly Notices* have continued to appear at regular intervals, and though the number and length of the papers have been sadly diminished their quality has shown no falling off. By virtue of an arrangement with the Editors of *The Observatory* each Fellow has received, and will continue to receive, that unique record of astronomical activity, and even though debarred by geographical reasons from attendance at our meetings obtains, thanks to the unrivalled reportorial skill of the Editors, some idea of our discussions. We have offered hospitality to our sister society, the British Astronomical Association, and we have stimulated the growing interest in astronomical topics by several successful series of lectures to the Forces.

To our war-time Councils the unstinted thanks of the Fellows are due. Council, however, is primarily a body for making policy, and the decisions which it makes and the successful execution of its policies depend to a great extent upon the information supplied by the Officers, particularly the Secretaries and the Treasurer, and upon their administrative efficiency. Two of these Officers have been in harness throughout the whole of the war, and it is due in no small measure to the time so freely given, the knowledge and the wisdom of our retiring Treasurer, Mr. J. H. Reynolds, and of our Secretary, Mr. D. H. Sadler, that the Society has so successfully met the impact of war. That these contributions to us have been maintained in addition to their outstanding services to the country as a whole only adds to our admiration, and I think that rarely in our long history have two Fellows deserved better of the Society.

Our rejoicing at peace is somewhat tempered by the knowledge of the many serious problems which face us now and in the future. In view of the necessarily greatly increased cost of printing, of our office staff and of our library, the mere maintenance of our normal activities at their pre-war level will demand a much higher level of income than we now receive. More serious, however, is the state of observational astronomy in the country. That much of our telescopic equipment is inadequate, if not obsolescent, is only too well known, but what is not so generally recognized is the serious effect of the war on the staffs of the observatories. Practically every astronomer in the country has been engaged for the last six years in war-work of one kind or another, and so invaluable have been their services that there is little prospect that some of the more brilliant of them will be able to resume their former astronomical activities. To these losses are to be added a number of actual and impending retirements. In addition, post-graduate instruction has not been possible during the war, so that there can be no immediate prospect of filling the ranks with trained, though inexperienced, astronomers. In this gloomy picture there are only two high lights. The Royal Observatory at Greenwich, as is now well known to all of us, has been a vital factor in our victory, but thanks to the energy and initiative of the Astronomer Royal, for whose like we have to look back to the days of Airy, the Royal Observatory in equipment and trained staff is in a stronger position than ever before. Equally the amateur astronomers, who form the very backbone of our Society, have increased in number and activity; their contributions to solar physics, to the study of planetary detail, of variable stars and of meteors have continued without respite, and form a glorious page of astronomical history.

In spite of these bright spots, the absence of adequate telescopic equipment in our university and other observatories, and the shortage of trained astronomers, makes the future of astronomical observation in this country sombre indeed. These facts have not escaped the attention of our colleagues in other branches of science. During the war many of them have had the duty of visiting the United States, and when they have seen, as many of them have, the telescopes of the University of Chicago in the Yerkes and Macdonald Observatories, the telescopes of Harvard at its various observing stations, of the University of California at the Lick Observatory, and of Mount Wilson and the Palomar Observatories, associated with the California Institute of Technology, it is scarcely surprising that they too have wondered about the future of astronomical observation in this country. Within the last few months two distinguished physicists—not of Oxford, they are probably too tactful of my feelings—have expressed in my hearing the considered view that it would be in the interests of efficiency to close down our university observatories. They have pointed out that for the past twenty years the chief astronomical activity of this country has lain in the field of theoretical astronomy, and in view of this fact and the further fact of an observing climate which falls somewhat short of perfection, they have concluded that it would be the part of wisdom to cease to attempt to observe here. This view, though in not quite so extreme a form, has also been expressed by some of our own Fellows who have suggested that if money for new telescopes becomes available in this country, these telescopes should be erected in some more or less remote part of the Commonwealth where better conditions for observation prevail.

Now these views, honestly as they are held and convincingly as they are maintained, I believe to be fundamentally wrong. This afternoon, therefore, I should like to put forward an alternative view for your consideration, and this I can best do in three stages. First I wish to consider the present state of observational astronomy in this country, which shows the need for at least one large telescope here, secondly to consider the requirements which such a telescope must satisfy, and finally to consider the reorganization of astronomy which must be effected to secure the most efficient use of such an instrument.

## 1. *The State of Observation in Britain and the Need for a Large Telescope*

1.1. *Physical Interpretation of Stellar Spectra.*—The points I wish to make could be illustrated by almost any example of astronomical research. That I choose for this purpose British contributions to the physical interpretation of stellar spectra is a consequence largely of my own special knowledge and interests. Following the pioneer work of Fraunhofer in 1820, observations of stellar spectra were commenced almost simultaneously in the sixties by Donati and Secchi in Italy, by Rutherfurd in the United States, by Carpenter at Greenwich and by Huggins in Britain. The first photographs of stellar spectra with the consequent extension of the known region into the near ultra-violet were made by Henry Draper in the United States and by Huggins here. While workers elsewhere tended to concentrate on the examination of a great many stars and to building up a system of spectral classification, Huggins and Miller commenced the characteristically British attack on the subject by attempting to identify the lines in the spectra of a few stars with those of terrestrially known elements, and succeeded in identifying in the stars lines due to hydrogen, iron, magnesium, silicon, and so on, as well as in establishing that the so-called "nebulium" lines arose from a non-identifiable source. Towards the end of the century, while Pickering, Miss Maury and Miss Cannon were building up the Harvard system of classification and photographing stars by the hundreds, Norman Lockyer at South Kensington, after his invaluable work on solar spectroscopy which had led to the identification and ultimate isolation of the element helium, commenced that detailed study of the laboratory conditions of excitation—using this word for the moment in the vaguest possible sense—of lines in stellar spectra. With

his collaborators, A. Fowler and F. E. Baxandall, Lockyer succeeded in showing that one element under varying conditions of excitation could produce two or more different kinds of spectrum. These he distinguished by the symbol for the element in the case of arc lines, thus $\lambda$ 4227 arises from *Ca*, and by the symbol with a prefix *p* for the spark lines, thus the H and K lines arise from *pCa*. In the case of silicon he was successful in recognizing no less than four stages of excitation, in this case distinguished by Roman numerals, so that the arc lines were designated by *Si*I, spark lines by *Si*II, and condensed spark lines by *Si*III and by *Si*IV.

Lockyer's work was continued with particular brilliance by A. Fowler. In addition to his identification of molecular bands such as *TiO* in the M-type stars and of *MgH* in sunspots, and of the spark spectrum of helium as the origin of the line $\lambda$ 4686 in O-type stars, Fowler's great contribution was his extension of the work of Balmer and Rydberg. Using their methods Fowler succeeded in showing that the arc lines of an element gave series with a Rydberg constant *R*, and spark lines series with a constant $4R$, so that ultimately he was able to show that the four spectra found by Lockyer in silicon were characterized respectively by the Rydberg constants *R*, $4R$, $9R$ and $16R$. With the development of Bohr's theory in 1914 this behaviour was recognized to be a consequence of the fact that the lines in a series arose from transitions between a common lower state and a number of upper excited states, the energies of which varied as the square of the charge carried on the atomic core. Hence line series with a constant *R* arose from an electron making transitions between states whose energy was determined by an atomic core with a positive charge of unity, that is these lines arose from a neutral atom, while line series with a constant $4R$ arose from states with energy determined by an atomic core with a positive charge of two units, that is from an atom which had lost one electron or had been ionized.

By 1919 the suggestion had already been made by Lindemann that such ionization would arise in thermodynamical equilibrium as a result either of high temperature or low pressure. This suggestion was closely followed by M. N. Saha who had come in 1920 from India and Germany to work in Fowler's laboratory, and who succeeded in developing a quantitative relation between the degree of ionization and the temperature and the pressure in an enclosure in thermodynamical equilibrium. Using the wealth of observational and experimental material available in Fowler's laboratory, Saha succeeded in establishing, from the marginal appearance of lines in stellar spectra, a temperature scale for the Harvard classification. The marginal appearance of a line is an unsatisfactory indication since it depends upon the abundance of the element as well as upon the degree of ionization, and it was left to R. H. Fowler and E. A. Milne to show that, if account were taken both of excitation (now in the exact sense of the word) in accordance with the Boltzmann relation and ionization in accordance with Saha's theory, the subordinate lines of an atom in an enclosure with a constant partial pressure of free electrons would show a maximum characteristic of the temperature. Such maxima were well known to occur in the Harvard sequence, and on the assumptions of local thermodynamic equilibrium, common partial pressure of free electrons in all stellar atmospheres and a common relative abundance of elements, Fowler and Milne succeeded, making use of Baxandall's unrivalled knowledge of line identifications in stellar spectra, in fixing this common pressure of free electrons at $1{\cdot}3 \times 10^{-4}$ atmospheres and setting up the now generally accepted temperature scale ranging from 4000° K for the M-type stars to 35,000° K for the O-type stars.

This successful physical interpretation of stellar spectra represents, it will be generally agreed, the greatest triumph of astrophysics up to that time. Though significant contributions were made by astronomers and physicists in other countries, the investigation both in its inception and in all stages up to its successful conclusion was primarily a British achievement. Unfortunately the further application of Fowler and Milne's theory to the determination of the temperature and pressure in the atmospheres of

individual stars could not be made here, since it demanded high disperson stellar spectra such as could only be obtained with large reflectors. We are not surprised therefore that this next step was taken in 1928 by Russell and Adams working at the Mount Wilson Observatory with the magnificent stellar spectra obtained at the Coudé focus of the 100-inch telescope. By means of an ingenious empirical calibration of estimated line intensities with the numbers of atoms producing the line per square cm. column of the stellar atmosphere (subsequently to be given firm theoretical basis by the work of Minnaert and others on the "curve of growth"), Russell and Adams succeeded in giving temperatures and pressures in the atmospheres of a number of stars in terms of those prevailing in the solar atmosphere. Subsequent work by Struve and Dunham has led to a great extension of our knowledge, and particularly to the important part played by turbulence in such atmospheres, though many of the surprising results obtained by Russell and Adams are still unexplained and the whole field may be described as being relatively unexplored. There is a great need here for a re-introduction of those detailed and critical studies so characteristic of British astronomy at its best.

1.2. *Relation between Theory and Observation.*—From this one not uncharacteristic story of astronomical research two conclusions may be drawn. The first refers to the very close relationship which exists between theory and observation. It cannot fail to have been noticed that the theoretical work on the interpretation of stellar spectra was in each case carried out in the closest possible collaboration with the observers at the place where the observational and experimental material was available. Thus Saha came to A. Fowler's laboratory to develop his theory and to set up his scale of stellar temperatures, R. H. Fowler and E. A. Milne were already in Cambridge and inevitably made extensive use of Baxendall's knowledge and the collection of small dispersion stellar spectra available at the Solar Physics Observatory, while Russell, who was one of the first theorists to realize the significance of the work of A. Fowler and Saha and who did much to extend their results, went from Princeton to Mount Wilson in order to apply the theory to the high dispersion stellar spectra available there alone. Nor is this surprising. The division of labour between the theorist and the observer is not an ideal arrangement, but only one forced upon us by the recent great extensions of theoretical knowledge. The theorist must have at his command vast tracts of knowledge in mathematics and theoretical physics, and it is no longer possible for him to have at the same time that detailed knowledge of observational technique and its limitations which modern developments have made possible. Probably the last astronomer equally skilled in both fields was K. Schwarzschild whose contributions to our subject still serve as a source for all modern developments. The ideal astronomer would be another Schwarzschild, but since that is now impossible the next best thing is the most intimate possible association between the observer and the theorist. In this way and this way alone can astronomy hope to advance.

Now if, as has already been proposed by some physicists and astronomers, the university observatories are moved from Britain to places where better observing conditions exist, then the ultimate consequence must be that the theorists will inevitably follow them there. I say *ultimately*, because I would not expect those of our theorists who are already established to follow the observers. They would presumably continue their work here, inevitably more and more divorced from observational actuality, but the younger generation, who might be expected to take up their mantles, would equally inevitably find their interest and work in branches of physics, other than astronomy, in which active experimental work was going on in their vicinity. I venture to predict therefore that the disappearance of the university observatories as centres of observational astronomy in Britain would inevitably be coupled with the disappearance of astronomy as a whole from our universities. Nor would astronomy be the only subject which would suffer. Reviewing the joint history of physics and astronomy, it is remarkable how much the advance of physics has depended upon observational discoveries in astronomy. For

example Balmer's recognition of the series law in hydrogen depended upon Huggins's discovery of the ultra-violet hydrogen lines, Bohr's theory was built upon and had its first noteworthy triumph in Fowler's work on ionized helium, while the discovery of helium itself stemmed from Lockyer's studies of the solar spectrum. I suggest therefore that the first conclusion to be drawn from the history of the interpretation of stellar spectra is that the closing of the university observatories would ultimately lead to the disappearance of astronomy from the universities, to the inevitable impairment not only of astronomy, both British and foreign, but to a lesser extent of related branches of science in the country.

1.3. *Need for Large Telescopes.*—The second conclusion that may be drawn from our brief historical survey is the need for the most modern equipment in telescopes and ancillary instruments in the observatories of the country. We gained the lead in spectroscopy by Huggins's application of the then new spectroscope to the study of the stars, and we maintained the lead just so long as our spectroscopes and the light-gathering power of the telescopes which fed them were at least comparable with those existing elsewhere. We lost the lead quite definitely in 1928 when high-dispersion spectra obtained with the 100-inch telescope at Mount Wilson became available for detailed study.

It is interesting to note how closely parallel have been the contributions to astronomy made in Great Britain and the United States, and the size and the number of telescopes which each country has had available for observation. In Table I are listed the new refractors, 20 inches in diameter and larger, and the new reflectors, 30 inches in diameter and larger, which have been added to the observatories of the two countries in each decade between 1880 and 1940. These additions to telescopic equipment are shown graphically in the figure, where each vertical strip shows the addition of a new telescope in the given decade, the height of the strip being proportional to the square of the aperture—that is, to the light-gathering power of the telescope. Two or three comments may be made on this table and figure.

Great Britain started the decade 1880–89 with the already available Newall 25-inch refractor and with A. A. Common's 36-inch reflector. In order to provide the funds for the 60-inch reflector built by him in the next decade, Common sold his 36-inch reflector to Crossley in this country, while the latter ultimately presented the instrument to the Lick Observatory where, in the hands of Keeler, Wright and others, it has been responsible for some magnificent observations. Though lost to Britain this original Common 36-inch was ultimately replaced by a similar instrument, first installed at South Kensington, and now ultimately at the Solar Physics Observatory where it has done much valuable work. In 1890 there was added to British observational equipment the 60-inch Common reflector. In its support system, in the fork-type mounting and with its double-slide plate-holder this instrument was the prototype of Ritchey's 60-inch reflector at Mount Wilson. After his death in 1903 Common's telescope was sold to Harvard, and the mirror, refigured by Fecker, is now doing excellent work at the Bloemfontein station of that observatory. The only noteworthy additions to British astronomical telescopes since 1900 have been the two closely similar 36-inch reflectors, made by Grubb, Parsons and installed at Edinburgh and Greenwich.

The United States started the decade of 1880–89 with the famous 36-inch refractor with the objective by Alvin Clark and the mounting by the Warner Swasey Co., together with the 36-inch Crossley reflector, built by A. A. Common. Mentioning only the outstanding telescopes, there were added in the next decade the Yerkes 40-inch refractor, in the following decade the 60-inch Mount Wilson reflector, by 1919 the 100-inch reflector, also at Mount Wilson, while in the final decade (1930–39) there were added the 61-inch Harvard reflector, the 69-inch Perkins reflector and the remarkably perfect 82-inch reflector of the McDonald Observatory. In our table and figure do not, of course, appear the projected 200-inch reflector to be installed on its completion at Palomar, nor the 48–72-inch Schmidt telescopes planned for Palomar and Harvard. Summarizing, it

is not unfair to say that up till 1910 the sizes of telescopes in Britain and the United States were roughly comparable, while the numbers of instruments in the two countries were not out of proportion to the populations. Since that date, however, while the United States has been adding new and larger instruments, we are worse off than we were at the beginning of the century when we had the Common 60-inch reflector. It is therefore scarcely surprising that in the last twenty or thirty years British observational astronomy has fallen far behind that in the United States.

1.4. *Why no Large Telescopes in Britain?*—The failure to build large telescopes here in recent years is usually attributed to three reasons. The first of these is that the seeing, or steadiness of stellar images is too poor to permit the use of a large telescope in Britain. There appears, however, to be little evidence for any marked difference in seeing conditions here and on the American continent. The very fact that Herschel, Lord Rosse and Common successively and successfully used apertures of 48, 72 and 60 inches indeed suggests that the seeing here must be at least comparable with that prevailing in other places where large instruments are used. In this connection I was interested recently to see in a letter from an astronomer, now working in a site selected with the greatest possible care to ensure the best possible seeing, and who has had experience of observing conditions both here and on the American continent, the following statement:—

> "I am as yet unconvinced that the steadiness of the seeing [at this specially selected site] is appreciably better on the average than it is in England, although we may have spells when it is very good."

This statement, the evidence of other observers with transatlantic observational experience which might be quoted, and the successful use of telescopes up to an aperture of 6 feet all make it probable that seeing conditions in Britain would permit the successful use of large apertures here.

The second reason why, it is suggested, no large telescopes have been built here of recent years is the infrequency of clear nights. No one of us who has experienced the disappointments of observation in this climate is likely to maintain that Britain offers an ideal site for an astronomical observatory. On the other hand we are not likely to forget that our great predecessors, Herschel, Huggins and Lockyer, in spite of the fewness of clear nights, made contributions to observational astronomy as much in advance of their time as anything done subsequently in places favoured by more clear nights per year. Two factors contributed to their success. First they selected problems where the ratio of time spent at the telescope to that spent in subsequent measurement, reduction and discussion was small, thus minimizing the disadvantages of cloudy weather. The number of such problems has not decreased since their time, rather the contrary, so that many astronomers working with large telescopes in sites with many clear nights in a year are forced to pass by these most interesting problems so that their observation and reduction do not get too greatly out of step. The second reason for the success of our predecessors lay in the fact that their equipment at the time was the most efficient of its kind. It is a pretty safe rule that the less frequent the opportunities for observation, the more efficient must be the instrument and its mounting to take full advantage of these fleeting opportunities. On a site with many clear nights useful work can be done with a small and relatively inefficient instrument (on variable stars for example), while with a few clear nights only the best and largest instruments can successfully be used for the study of modern observational problems. To say all this is not, however, to deny that a large instrument could employ more astronomers if located on the west coast of the American continent or on the high plateau of South Africa than it could in Britain. The telescope, however, is made for man, not man for the telescope, and if observational astronomy in this country is to keep abreast of that in other countries the very rarity of clear nights here demands the best possible instrument.

The third reason why, it is suggested, no large telescopes have been built here of

TABLE I

*New Telescopes in Britain and United States*

| Decade | Great Britain | | | United States | | |
|---|---|---|---|---|---|---|
| | Diam. | *f*/- | Remarks | Diam. | *f*/- | Remarks |
| 1880–89 | 25 | 14·4 | Newall refractor, Cambridge | 23 | 15·1 | Princeton refractor |
| | | | | 26 | 15 | Naval Obs., Washington, refractor |
| | 36 | 5·8 | Common reflector; sold Crossley; presented Lick Observatory | 26 | 15·1 | Leander McCormick refractor |
| | | | | 36 | 19·1 | Lick Observatory refractor |
| | | | | 36 | 5·8 | Crossley reflector, Lick |
| | 36 | 3·75 | Common reflector now at Solar Physics Observatory, Cambridge | | | |
| 1890–99 | 26 | 10·3 | Thompson phot. refractor | 20 | 16·7 | Van Vleck refractor |
| | 28 | 11·9 | Vis. refractor, Greenwich | 20 | 16·8 | Chamberlain refractor, Denver |
| | 30 | 4·6 | Thompson reflector, Greenwich | 24·1 | 16 | Lowell refractor |
| | 30 | | Norman Lockyer Observatory, Sidmouth | 40 | 19·1 | Yerkes refractor |
| | 60 | 5·1 | Common reflector, ultimately sold Harvard | 44 | 5·0 | Lowell reflector |
| 1900–09 | 24 | 11·2 | Radcliffe phot. refractor, now Univ. London Observatory | 20 | 16·8 | Chabot (Oakland) refractor |
| | | | | 30 | 5·0 | Allegheny reflector |
| | | | | 60 | 5·0 | Mt. Wilson reflector |
| 1910–19 | | | | 24 | 18·0 | Sproul Observatory refractor |
| | | | | 30 | 18·5 | Allegheny phot. refractor |
| | | | | 37 | 6·1 | Ann Arbor reflector |
| | | | | 100 | 5·1 | Mt. Wilson reflector |
| 1920–29 | 36 | 5·0 | Edinburgh reflector | 36 | 5·0 | Steward Observatory, Tucson |
| 1930–39 | 36 | 5·0 | Greenwich reflector | 18 | 2·0 | 18–26 Palomar Schmidt |
| | | | | 20 | 7·0 | Lick phot. refractor |
| | | | | 24 | 3·5 | 24–33 Harvard Schmidt |
| | | | | 24 | 3·5 | 24–36 Case School Schmidt |
| | | | | 32 | 4·0 | Jenkintown reflector |
| | | | | 36 | 5·0 | Goethe-Link A.T.M. reflector |
| | | | | 61 | 5·1 | Oak Ridge, Harvard, reflector |
| | | | | 69 | 4·3 | Perkins reflector |
| | | | | 82 | 4·0 | McDonald Observatory reflector |

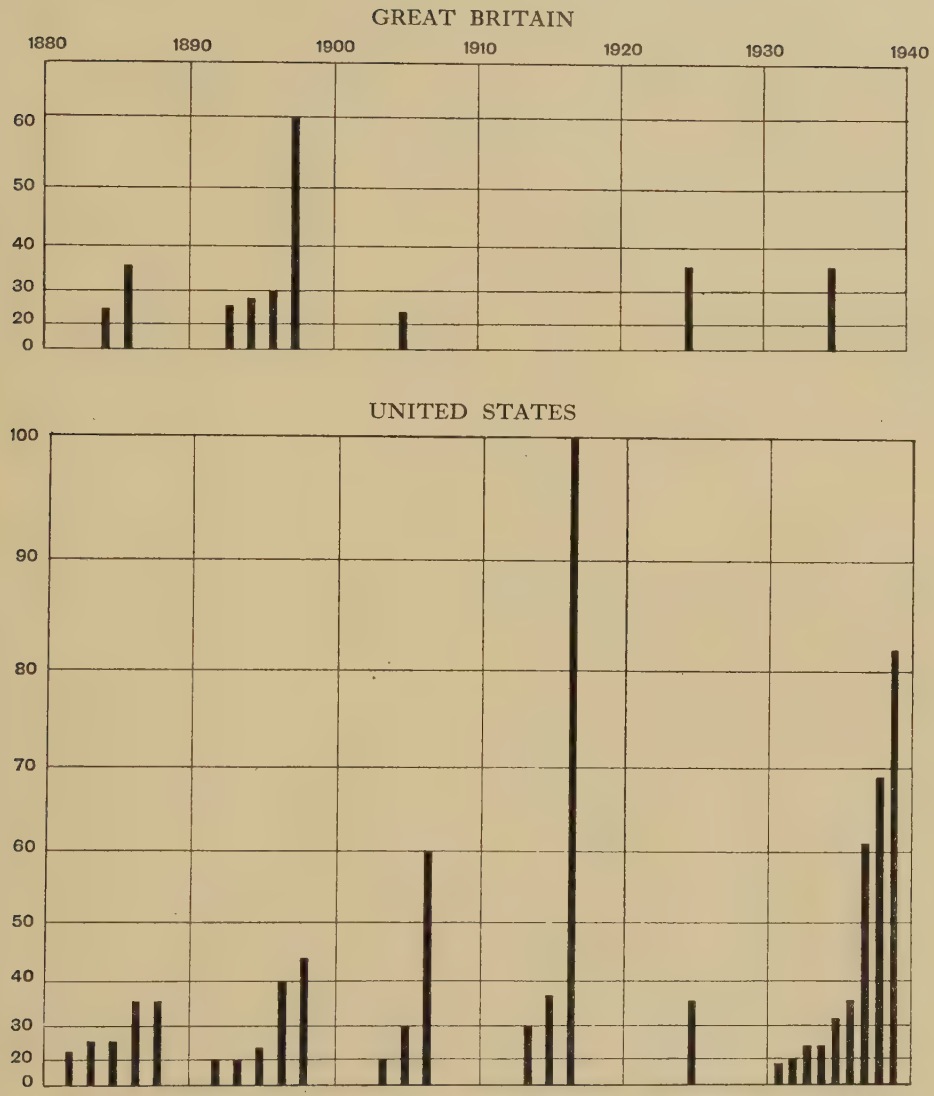



FIG. 1.—*Telescopes added in each decade to the astronomical equipment of Great Britain and the United States. Each black strip represents a single instrument, the height of the strip being proportional to the square of the aperture of the telescope, that is to its light-gathering power, while the abscissa of the strip shows the decade in which it was first brought into use. (For Great Britain the diagram is not complete, since in the decade* 1880–89 two, *not one,* 36*-inch reflectors, and in the decade* 1890–99 two, *not one,* 30*-inch reflectors should be shown—compare Table* I).

recent years has been the lack of those very wealthy men who, by their foresight and generosity, have done so much for the development of astronomy in the United States. In addition, it should be added, there has never been a British Hale who has combined scientific talent of the very first order with the ability to inspire the wealthy with an exciting vision of astronomical research. If we are not a country of wealthy individuals, we are a country which has learned in a hard school the vital importance of research both in science and technology, and it is indeed fortunate that this lesson seems to have been as fully appreciated by the Government as it has by the country as a whole. If the Society could present a reasoned and convincing statement of the need for a large telescope in Britain, I am confident that the Government would consider an application for a grant to build such an instrument with the same sympathy and understanding that they have shown to other plans for the development of science.

To summarize, I have tried to show that the future progress of astronomy in Great Britain depends upon the construction of at least one large telescope, and that with a suitable choice of problems there are no climatic reasons why such an instrument could not be effectively used here. Assuming that I have carried you at least part way in this argument, let us next consider the requirements which such an instrument must satisfy.

## 2. *Requirements for a Large Telescope in Britain*

2.1. *Limitations on Use of Telescope.*—Poor "seeing" and the finite resolving power of the photographic plate are the two main limitations on the use of a large telescope. Poor seeing arises from regions of variable refractive index in the Earth's atmosphere, and assuming these regions to be roughly comparable in size the effect on the seeing depends upon their distance from the telescope. When they are close and so subtend a large angular diameter, it is clear that all the stars comprised within this large angle will be equally affected by the one region. In this case all the stars comprised in the field show equal small angular displacements, and we get the simultaneous displacements discovered by Schlesinger and discussed by him in his George Darwin Lecture. It is this effect of seeing which ultimately limits the accuracy attainable in visual and photographic astrometry. The non-homogeneous regions, distant from the telescope by a mile or more, will clearly subtend small angles, and each star in the field of the telescope will tend to be affected by a different region. If the linear extent of these regions is comparable with the entrance pupil of the instrument, the star will appear to suffer a bodily displacement, as for example in the "twinkling" of stars seen with the unaided eye, but if the linear extent is small a corrugated wave front of varying retardation will be incident on the entrance pupil. In this latter event, usually encountered with instruments greater than 12 inches in diameter, an image is obtained no matter how optically perfect the telescope, which is an extended disk, the so-called tremor disk. The angular diameter of the tremor disk of a star affords a quantitative measure of the quality of seeing; under very good conditions this may have a diameter as small as one second of arc increasing to some five seconds under poor conditions. Tremor disks as small as 0·03 second have been reported by Danjon and Couder at Forcalquier in the Lower Alps, while "ballon" images larger than five seconds are not infrequently encountered on the west coast of the American continent. Experience suggests that under average good conditions of seeing in Britain the tremor disk has a diameter of some two seconds, and the usable extent of the angular field of our large instrument will be set by the requirement that the optical disk of least confusion produced by the various aberrations of the optical system does not exceed this limit of two seconds.

The second limitation arises from the grain of the photographic plate. From the work of Mees and Ross it is known that this grain limits the linear distance on the plate which suffices clearly to separate, or resolve, two adjacent line images. For the average fast emulsion of high contrast this resolving power corresponds to some 25 lines per mm.,

so that two star images, each 0·02 mm. in diameter, will be clearly separated on such a photographic plate if their centres are distant by 0·04 mm. If we are to attain the full resolution which a tremor disk of two seconds diameter will allow, it is clear that the focal length of our telescope must be such as to give a scale of 0·02 mm. equal to two seconds of arc, that is a minimum focal length of some 7 feet. Allowing for periods of exceptionally good seeing, when tremor disks may be as small as one second in diameter, this minimum focal length should be increased to 14 feet.

2.2. *Telescope for Direct Photography.*—The axial spherical aberration of the Newtonian reflector is corrected by parabolizing the main mirror, but off the axis this telescope gives images affected by coma and astigmatism. From the calculations by Schwarzschild in 1905 it is known that the disk of least confusion, due to these two aberrations combined, attains an angular diameter of two seconds (the diameter of the tremor disk under conditions of good average seeing) two minutes of arc from the axis of an $f/3$ Newtonian reflector, five minutes of arc from the axis of an $f/5$, and 30 minutes from the axis of an $f/15$ reflector. To cover a field one degree square, to the limit of definition imposed by average good conditions of seeing with the usual $f/5$ Newtonian reflector, would therefore require some 36 separate exposures. This is an insuperable limitation to the use of a large Newtonian reflector for direct photography in Britain, where the number of clear nights is relatively small, and this limitation is made at least twice as serious when an additional star field must be superposed on each plate for photometric purposes.

Two main methods have been proposed to overcome the limited angular field of the Newtonian reflector. On the one hand Schwarzschild in 1905 theoretically examined the properties of two-mirror systems for which both spherical aberration and coma were eliminated to the third order, and found a number of such systems, with either concave or convex secondary mirrors, which satisfied this requirement. The mirrors of these aplanats are difficult to figure and their alignment must be rigidly maintained in all telescope positions, but nevertheless successful examples up to 24 inches diameter have been constructed in the United States. Variants of Schwarzschild's design have been proposed and constructed by Couder and Chrétien; in the former, in addition to the elimination of spherical aberration and coma, the astigmatism is absent on a curved focal surface, while in the latter, at the expense of a curved field and astigmatism, a conveniently short tube length is obtained.

The other and a highly original attack on the problem was made by Bernhard Schmidt at Hamburg in 1930. Noting that a perfectly spherical mirror has no principal optical axis, it is clear that parallel beams, incident at varying angles on a stop at the centre of curvature of such a spherical mirror, will give images suffering from spherical aberration, but not from coma or astigmatism. The spherical aberration of these beams is such that the marginal rays are focused short of the central rays, and Schmidt showed that by placing a zero power correcting plate at the centre of curvature, figured so as slightly to diverge the incident marginal rays and slightly to converge the central rays, the spherical aberration of the system could be eliminated. Such a system, consisting of a truly spherical mirror with a correcting plate at its centre of curvature, will thus yield images free to the third order from spherical aberration, coma and astigmatism, but suffering from chromatic difference of spherical aberration introduced by the correcting plate, curvature of field and distortion. The two latter aberrations are not serious from an astronomical point of view, while the chromatic aberration can be minimized, as Schmidt pointed out, by figuring the correcting plate so as to bring the focal surface three-quarters of the way from the paraxial to the marginal focus, or very largely eliminated by achromatizing the correcting plate. In order to avoid vignetting at the edges of the field, the diameter $D_2$ of the stop at the centre of curvature is related to $D_1$, the diameter of the spherical mirror, and $\theta$ the angular diameter of the field, by the relation

$$D_1 = D_2 + 2f\theta$$

where $f$ is the focal length of the mirror. If we take the angular diameter of the field to be limited to $\theta = D_2/4f$ (to reduce fifth and higher order aberrations to negligible proportions), then an unvignetted field of this angular diameter will be secured by making the spherical mirror with a diameter fifty per cent. greater than that of the stop at the centre of curvature.

The great gain in the usable field of the Schmidt telescope is obtained only at a price. Thus the focal surface is a convex sphere of radius $f$, it is somewhat inaccessibly located half-way between the correcting plate and the mirror, the tube length (which determines the size of the dome and therefore a considerable fraction of the cost of the whole installation) is twice that of a Newtonian reflector of the same focal length, and finally the correcting plate is exceedingly difficult to figure. Various modifications to the Schmidt telescope have been proposed to overcome these disadvantages. Thus J. G. Baker and E. H. Linfoot have suggested the use of two-mirror systems with correcting plates. These have the initial advantage of giving the desired short tube length, and in Baker's design are anastigmatic aplanats with flat fields, somewhat inaccessibly located, at the cost of introducing non-spherical surfaces on one or both mirrors, while in Linfoot's design the field is both flat and accessible and the mirrors are true spheres, but at the cost of re-introducing astigmatism. The difficulty of figuring the correcting Schmidt plate has been avoided by Maksutov who substitutes for it a steep meniscus lens of very nearly zero power. These several interesting modifications of the original Schmidt design are likely to be useful for small telescopes and for cameras designed for photography from aircraft, but experience suggests that in the large telescopes required for astronomical purposes the original Schmidt telescope is likely to be the most practicable and useful type. Its curved field and the inaccessible position of the photographic plate are not serious disadvantages in a large instrument, and admit of simple mechanical solutions, while the doubled tube length and the difficulty of figuring the correcting plate are small prices to pay for the greatly increased field of the Schmidt over the Newtonian telescope. Further, so much experience has now been gained, particularly in the United States, on figuring large correcting plates that 48–72-inch Schmidt telescopes are now under construction for Palomar and for Harvard College Observatory.

In order to have something concrete to consider, I should like to suggest the construction here of an $f/4$ Schmidt telescope with an aperture of 49–74 inches. This would have a focal length of $49 \times 4 = 196$ inches, or in excess of the minimum focal length of 14 feet required to secure full photographic resolving power under optimum conditions of seeing (Section 2.1). The tube length (twice the focal length) would be under 33 feet, so that the mounting and dome of the telescope could be very closely similar to that of the 74-inch Radcliffe telescope at Pretoria. For a correcting plate of the full 74-inches aperture and a 49-inch stop half-way between the plate and the mirror, the angular diameter of the usable field would be some seven degrees, while from the predictions of Whipple and Rubenstein it would reach a limiting photographic magnitude (when the light of the night sky produces a density of unity on the photographic plate) of $20^{m}{\cdot}1$ in an exposure of some seven hours. If the stop were opened to 60-inches diameter, the limiting magnitude would be 20·4 in an exposure of under five hours, the unvignetted field being reduced to a diameter of 4·1 degrees. Such an instrument would have a considerable degree of flexibility, and would enable useful work to be done in the problems accessible to direct photography, even for periods of clear weather of only a few hours duration.

2.3. *Application of Telescope to Slit-Spectroscopy.*—Our Schmidt telescope would be usable at full efficiency for direct photography only during the "dark of the Moon". The ideal arrangement would then be one where during moonlight the same telescope could be used as a condensing system for a powerful slit-spectroscope, the more so since with our long tradition of work in stellar spectroscopy there are many problems in this field in which British astronomers are vitally interested. There are three possible methods

whereby the Schmidt telescope could be modified so as to admit of its use for slit-spectroscopy.

If the correcting plate and stop of the telescope were removed, the full aperture of our spherical 74-inch mirror of focal length 196 inches would be available as a condensing system for our spectroscope. Place now a convex spherical mirror of 13·3 inches diameter and 82·8 inches radius of curvature with its pole 34·4 inches inside the paraxial focus of the main mirror, and we would get a paraxial image formed 20 feet away from the pole of this mirror with an aperture ratio of $f/18$. By two additional reflections from small fixed plane mirrors, as in the Radcliffe telescope, the paraxial focus could be brought to a fixed Coudé focus at the southern end of the polar axis. A trigonometrical ray trace through this system shows that the marginal rays, making an angle 1° 46′ 26″·4 with the axis are focused 29·1 inches inside the paraxial focus, rays making an angle of 1° 07′ 53″·2 with the axis, 14·0 inches inside, and rays making an angle of 0° 34′ 01″·0, 3·9 inches inside. The disk of least confusion would have a diameter of 0·45 inch. If our slit were placed in this position at the Coudé focus, it would transmit an exceedingly small fraction of the incident star light, but by means of a Bowen image-slicer this difficulty could to some extent be overcome.

In this optical device a small mirror turns the beam from the telescope so that it passes tangentially along the plane of the slit. This beam is then "sliced" by a series of small mirrors placed over the slit proper, and turned through 90° to fall on the collimator of the spectroscope. The result is a spectrum of correspondingly increased height, but with the same flux incident per unit area on the photographic plate. Just short of the focal plane of the camera, however, is placed a cylindrical lens (preferably more than one to reduce spherical aberration), so that the spectrum is reduced to a height of approximately 1 mm. and the flux per unit area in the spectrum correspondingly increased. Theory and experience suggest that the Bowen image-slicer with the ordinary stellar tremor disk gives an increased efficiency of some ten times at the Coudé focus of a large telescope, and clearly it would give at least as large a gain for our telescope with its very large disk of least confusion. On account, however, of the spherical aberration responsible for this large disk, some of the light turned into the spectroscope by the image-slicer would tend to fall outside the collimator, and further the illumination of the collimator would be exceedingly non-uniform, thus putting a very considerable strain on the perfection of the optical parts of the spectroscope.

The second method of adapting our Schmidt telescope for slit-spectroscopy would be to retain our convex mirror, but to figure it so as to eliminate the spherical aberration of the Coudé focus of the system. Multiplying the longitudinal spherical aberration, found immediately above for the system with the convex sphere, by $\frac{1}{2}\sin U'$, where $U'$ is the angle the rays make with the optical axis, and integrating with respect to $\sin U'$, we get an approximate expression for the amount by which the convex sphere would have to be turned down to eliminate the spherical aberration of the system. At the margin this would amount to 0·0038 inch, resulting in a convex mirror, small though it is, which would be very difficult to figure and which would probably require testing in combination with the 74-inch sphere with a full 74-inch flat. However, the gain in definition at the Coudé focus and the greatly increased efficiency of the spectrograph, especially if used with the Bowen image-slicer to reduce the loss of light due to the tremor disk proper, would fully justify the extra labour and cost.

The third and undoubtedly the best method of adapting the Schmidt reflector for slit-spectroscopy would be, as already suggested in Section 2.2, to make the correcting plate to the full 74-inch aperture of the mirror. In this case we would have an image free from spherical aberration over the full aperture of the 74-inch mirror, and by introducing the usual Cassegrain hyperboloid we would obtain an image free from spherical aberration, and of any desired aperture ratio (preferably about $f/30$), at the Coudé focus of the system. The figuring of this full-size correcting plate would be more difficult

than turning down the edge of the convex mirror as in the second method, and like it would presumably involve frequent testing with a full-sized plane mirror. However, the great flexibility of the resulting telescope both for spectroscopy and for direct photography (Section 2.2) would be a strong point in favour of this very nearly ideal system.

2.4. *Probable Cost of Telescope.*—Our proposed telescope, as we have already seen, would in its mounting and general appearance, though not in its optical parts, be very similar to the 74-inch Radcliffe telescope at Pretoria. The present-day cost of that instrument will therefore give us some idea of the sum needed for our projected instrument. I am indebted to Mr. G. M. Sisson, the Managing Director of Grubb, Parsons for the following figures of the probable cost to-day of a duplicate of the Radcliffe instrument:—

| | |
|---|---|
| Mounting, complete | £32,000 |
| Optical parts | 13,500 |
| Circular steel building | 6,500 |
| Turret | 15,000 |
| | £67,000 |

Allowing for the additional cost of figuring the Schmidt correcting plate, offset to some extent by not having to parabolize the main mirror, and allowing for the cost of a good Coudé spectroscope with one or more gratings, three large prisms and a variety of cameras, it would appear that our required instrument and dome could be obtained for under £100,000. This is not much more than the cost of the bricks and mortar of a modern laboratory for research in physics or chemistry.

## 3. *Organization of University Astronomy in Britain*

3.1. *Ideal Organization.*—An instrument such as we are contemplating must necessarily be placed on a site with the greatest possible number of clear nights per year. Presumably therefore it would have to be erected somewhere in the south of England and in a place remote from any of the universities now provided with their own observatories. The ideal arrangement, from the point of view of efficiency in research, would be to centralize all the astronomical activity of the university and private observatories about the telescope at this site. Undergraduate instruction in the various universities would still have to be continued there, and could presumably be carried out by the return during term time of astronomers from the Central University Observatory to the several universities, while graduate instruction would be carried out primarily at this observatory itself.

Such centralization would permit of two developments which no single university observatory can now afford, but which are of vital significance for the development of observational astronomy in this country. The one of these would be a department for the study of applied optics. The importance of this was realized by Hale in founding the Mount Wilson Observatory, and some of the success of that famous institution may fairly be attributed to its active optical shop. Equally there can be little doubt that the Institut d'Optique has played no small part in the recent and remarkable revival of observational astronomy in France. Such work would be indispensable for the future development of observational astronomy here, for though the erection of a large telescope would put us temporarily in the front rank, we cannot expect our colleagues in other countries to remain content with their present instruments indefinitely. Unless we took out the insurance that an active study of applied optics would provide, we would be faced in another ten or twenty years with the situation so familiar to us during the war of "too little and too late". A department for applied optics in the Central University Observatory would have as its primary function the *theoretical* study of various forms of optical instruments, especially those used in conjunction with the 74-inch telescope,

with the intention of so increasing their efficiency that in combination with our single telescope we could keep step with the increased light-gathering power of larger instruments in other countries.

The second desirable development in connection with the Central University Observatory would be a modern laboratory for spectroscopic research of astronomical importance. Once again we may point to the similar development by Hale at Mount Wilson, to say nothing of the developments at South Kensington under Lockyer and Fowler where the spectroscopic laboratory very much overshadowed astronomical observation proper. For the ten years commencing in 1920 astrophysicists gained enormously from the exceedingly active spectroscopic research carried out by physicists all over the world, but now, with the emphasis not unnaturally on nuclear physics, it is evident that astronomers will once again have to be self-supporting in spectroscopic research. Already it is clear that future development in astrophysics will depend upon extensive laboratory investigations, as for example on determination of absolute values of oscillator strengths, or measurement of continuous absorption coefficients, and such requirements will undoubtedly increase in step with our growing knowledge.

Summarizing, we may picture this ideal Central University Observatory located in the best possible astronomical site in the country, and with equipment consisting of its 74-inch telescope together with such modern apparatus as is now at the disposal of the existing university observatories. With a staff composed of all the active observational astronomers in the university and private observatories, with the assistance of and closest possible collaboration with their theoretical colleagues, and with departments for the study of applied optics and laboratory spectroscopy, we might reasonably anticipate that Britain would once again take its place in the van of astronomical research.

3.2. *Immediate Practical Steps.*—Now while there is much to be said for such an ultimate organization of university astronomy in Britain, it is probably not an immediately realizable ideal. For one thing, and not improperly, the universities, while wishing to make use of the proposed 74-inch telescope, may prefer to retain their own observatories and astronomical departments. In any event we should have to wait a long time before the universities themselves would be prepared to take the initiative and to pool their resources in order to build such a telescope and central observatory. The Society, speaking authoritatively for astronomy, can alone save this situation and take the necessary steps towards securing the first essential for a revival of observational astronomy in Britain —a large telescope.

As an immediate practical step I should therefore like to suggest the desirability of the Society making an application to the Government Grant Committee of the Royal Society for the sum of £100,000 to build the proposed large telescope. This application would have to be backed by a comprehensive statement of the need for such an instrument and a sketch of the proposed method of administration. In this connection it would appear that the telescope should be located on the best possible site and be provided with a skeleton staff consisting of, say, a director, a junior observer, and a mechanic as night assistant for maintaining the instrument; their salaries and the cost of maintenance could be met by a grant to be applied for from the University Grants Committee. The policy governing the use of the instrument would be laid down by a Board of Management, of whom at least half the members should be suitably qualified Fellows appointed by the Society; its duty would be to consider applications for the use of the instrument by the various university and other observatories in the country, and to arrange these, in consultation with the observatory director, in various categories as to priority. The actual observation would of course be normally carried out by the astronomer suggesting the problem, while it would be one of the duties of the director and the junior observer of the skeleton staff to observe with the instrument in any gaps in the official programme. Such an immediate arrangement would secure for British astronomy the large telescope which it must have, and would at the same time ensure its efficient use, while leaving for